NOVEMBER, 1949

The WELDING JOURNAL

Official Publication of the American Welding Society

EIGHT WINNERS
FOR MILD STEEL WELDING

In the "Select 70"—seventy electrode types designed and selected by Metal & Thermit to cover every welding requirement at peak performance—eight rods matched to the various demands of mild steel welding permit easy choice of the *right* electrode for any mild steel job.

GENEX—for all-position work and bridging gaps.

TYPE FHP & TYPE F—for high speed, highest quality positioned work.

TYPE R—for sound weld metal on jobs involving vertical and overhead welding.

TYPE A—for general purpose welding with AC.

TYPE U—for structural welding with AC or DC.

ALTERNEX—for light gauge AC applications.

TYPE D—a new design for downhand welding and cover heads.

M & T products include M & T's "Select 70" group of electrodes. M & T AC and DC welding machines and M & T welding accessories. The line is complete, providing everything needed for arc welding . . . arc welding of top-notch quality. Write today for descriptive data.

METAL & THERMIT CORPORATION
120 Broadway • New York 5, N. Y.

NEW ARC WELDERS BOOST AC and DC PERFORMANCE

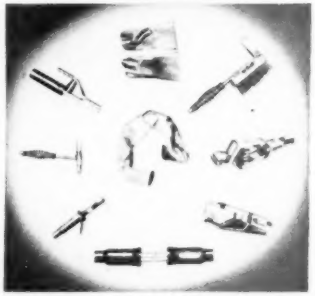
FASTER welding, better quality welds, lower power costs, and simplified maintenance are furnished by a new line of AC and DC arc welders introduced by Metal and Thermit Corporation.

Built-in capacitors for high power factor, wide current range for full rated output, and, fingertip, stepless current control for precise current setting are featured in the AC units. Available in 150 to 500 amp. models for manual arc welding, additional models for inert arc and automatic welding.

Full capacity, rugged duty DC arc welders are compact, light in weight—half the size and half the weight of older types—and are equipped with simplified current control, automatic electrode selector. Furnished in 150 to 400 amp. sets—motor driven, engine driven or belt drive.

Descriptive folder gives full particulars. Address Metal and Thermit Corporation, 120 Broadway, New York 5, N. Y.

ACCESSORY DIVIDENDS DECLARED



UNDERSCORING the importance of proper accessories to top welding performance, more and more fabricators are taking pains with selection of accessories. Speedier, lower cost, safer and improved welding are assured when such items as helmets, shields, holders, connectors, cleaning tools and protective clothing are carefully selected. And more and more fabricators—sold on M & T electrode and arc welder performance — are specifying the M & T line of "accessories to the perfect weld." For descriptive literature, address Metal and Thermit Corporation, 120 Broadway, New York 5, N. Y.

A welder that gives you both welding current and power!

HOBART A.C.–A.C.

arc welder–power plant

Actually two machines in one, this combination unit is today's biggest welder value. It brings you AC Arc Welding with an arc easier to hold than you ever dreamed possible. And in addition, AC Power of 5 K.W., 110 volts, 60 cycle, single phase for operating anywhere independent of power lines. Electric lights for night work, flood lights for emergency use. Operates electric tools, grinders, drills, compressors, motors and many other items used in your everyday jobs. Takes over when other electric service fails. Emergency use alone can save hundreds of dollars. It will pay you to investigate and compare.

This gasoline engine driven, electric starter equipped, 200 amp. capacity welder goes to the job, makes repairs without dismantling equipment and saves hours of valuable time and labor. If you want more arc welder value for your money, mail the coupon today.

HOBART BROTHERS CO., BOX WJ-119, TROY, OHIO

HOBART *"one of the world's largest builders of arc welders"*

A. C. Transformer Welders | D. C. Generator Only | Elec. Motor Driven D. C. Welders | Gas Drive D. C. Welder | D. C. Welder plus A. C. Power | Railway Type D. C. Welder | Hobart Weldmobile

HOBART RODS *SPUR* PRODUCTION!

For sound welds and faster welding with considerably less spatter loss, choose high quality Hobart Electrodes. Samples will be sent on request. Try them and compare the difference.

HOBART BROTHERS COMPANY, BOX WJ-119, TROY, OHIO

Please send more details on HOBART ARC WELDERS of ___amp. capacity, and other information checked:

- ☐ A. C. Welder plus A. C. Power
- ☐ Elec. Motor Driven D. C. Welders
- ☐ Gas Drive D. C. Welders
- ☐ Catalog Arc Welding Electrodes
- ☐ A. C. Transformer Welders
- ☐ Catalog on Welding Accessories

FREE! Use coupon and receive valuable "Guide to Better Welding"

NAME_____

FIRM_____

ADDRESS_____

THE AMERICAN WELDING SOCIETY

announces publication of

THE THIRD EDITION *of the* WELDING HANDBOOK

— Ready about January 1950 —

The largest collection of authorative welding information in one book.

The **Third Edition** *contains more information than previous editions, more tables, bigger index, many illustrations.*

Subjects covered include:

- **Welding Processes: Oxy-acetylene; Air-Acetylene; Oxy-Hydrogen; Pressure Gas; Carbon Arc; Shielded Metal-Arc; Bare Metal-Arc; Impregnated Tape Metal-Arc; Atomic Hydrogen; Inert-Gas Metal-Arc; Submerged Arc; Stud; Spot; Seam; Projection; Flash; Upset; Percussion; Forge; Thermit; Induction; Brazing.**
- **Flame Processes: Oxygen Cutting; Arc Cutting; Flame Heating and Heat Treating; Oxygen Machining.**
- **Other Processes: Surfacing; Metallizing; Soft Soldering.**
- **Metals and Alloys: Iron; Wrought Iron; Carbon Steels; Cast Irons and Steels; Low-Alloy Steels; Chromium Irons and Steels; Chromium-Nickel Steels; Austenitic Manganese Steels; Aluminum; Magnesium; Copper; Nickel; Lead; Zinc; Clad Steels.**
- **Applications: Buildings; Bridges; Machinery; Storage Tanks; Pressure Vessels and Boilers; Ships; Railroad Equipment; Automotive Products; Aircraft; Piping; Pipe Lines.**
- **General Subjects: Welding Symbols; Estimating Costs; Design of Joints; Nomenclature and Definitions; Filler Metal; General Engineering Tables; Safety; Welder Qualification; Training of Welding Personnel.**

- - - and others.

Priced at $12.00, you can reserve a copy now, in advance of publication, at a special advance sale price of $9.00. This will also assure early delivery since books will be shipped in order of their purchase.

NOTE: Sustaining (A) Members and Members (B) will each receive a free copy; Associate (C) Members will be able to purchase a single copy at $8.00.

To be sure of getting your copy early, and at a discount, fill out the order form below and remit with check, cash or money order. ***Offer expires January 15, 1950.***

RETURN ORDER FORM NOW ▼ FOLD AND TEAR HERE

ORDER FORM

AMERICAN WELDING SOCIETY
33 WEST 39th STREET
NEW YORK 18, N. Y.

Gentlemen: Please reserve ..... copies of the THIRD EDITION OF THE WELDING HANDBOOK for me (us) for which ..... Dollars in full payment is remitted herewith.

Name.....*Street Address*.....

City and State.....*Company* .....

Position.....

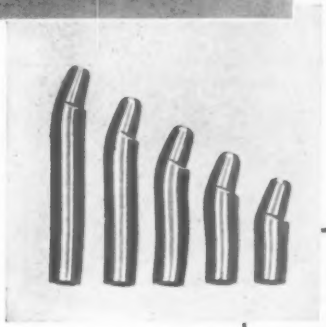
NOTE: This offer expires January 15, 1950.

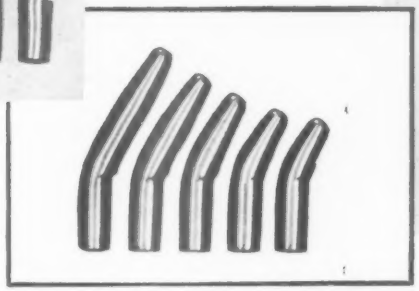
SPECIAL ANNOUNCEMENT FROM RESISTANCE WELDING ELECTRODE HEADQUARTERS

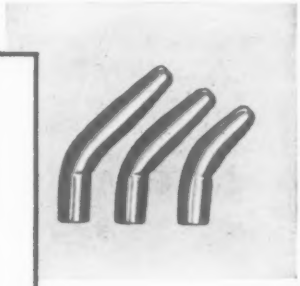
New

Mallory Single Bend Tips...

Developed to replace irregular forged or cast tips







Single bend tips can be supplied with bends of varying degrees from 0° to 45° and in varying over-all lengths at minimum costs. Illustrated is a cross-section of the many combinations of angles and over-all lengths available.

Tips made from rod stock possess superior physical and mechanical properties over tips made from castings or forgings. Mallory research and engineering have now developed single bend tips, *cold-formed* from standard, stocked, straight tips which may be used as replacements in gun or special applications where forged or cast tips are being used. Single bend tips also bring the cooling water closer to the welding face.

These new Mallory Single Bend Tips will stand greater impact... increase number of welds between dressings . . . give more uniform welds . . . *assure longer tip life.* And, they cost you less than cast or forged tips!

Mallory Single Bend Tips are available in #1 and #2 Morse Taper, and can be supplied with a bent welding face angle varying from 0° to approximately 45°.

Send details of your application or electrode requirements. Let us recommend the proper tip for your job.

In Canada, made and sold by Johnson Matthey & Mallory, Ltd., 110 Industry St., Toronto 15, Ontario.

Resistance Welding Tips, Holders, Dies, Rod and Bars, Castings, Forgings

P.R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WITH

Capacitors — Rectifiers
Contacts — Switches
Controls — Vibrators
Power Supplies
Resistance Welding Materials

the

WELDING JOURNAL

published for the advancement of the science and art of welding by the

AMERICAN WELDING SOCIETY

Editor

W. SPRARAGEN

OFFICERS

O. B. J. Fraser	*President*
H. W. Pierce	*1st Vice-President*
C. H. Jennings	*2nd Vice-President*
R. S. Donald	*Treasurer*
J. G. Magrath	*Secretary*
F. J. Mooney	*Asst. Secretary*
S. A. Greenberg	*Technical Secretary*

DISTRICT VICE-PRESIDENTS

District 41—New York and New England
H. S. Swan

District 42—Mid-Eastern
Gerard E. Claussen

District 43—Southern
L. C. Stiles

District 44—Central
Fred L. Plummer

District 45—Mid-Western
J. A. Grodrian

District 46—Mid-Southern
Ray L. Townsend

District 47—Western
W. F. Boyle

volume 28 **NOVEMBER, 1949** *number 11*

CONTENTS

technical papers, items and reports

Developments in Automatic Hard Facing, by H. W. Sharp 1037
Industrial Use of Modified Armor-Plate Steel, Discussion by R. Alden Webster 1039
Limits of Welding Positions, by W. L. Warner 1040
Oxyacetylene Flame Hardening in Commercial Heat Treatment, by J. T. Howat 1043
Oxygen-Acetylene Scarfing in the Steel Mill, by George Mersot 1052
Welding Metallurgy—Iron and Steel, by O. H. Henry, G. E. Claussen and G. E. Linnert 1056
Welding Conserves Steel, by T. R. Mullen 1064
Statement of the Ownership, Management, Circulation, etc. 1066
Flame Straightening, Forming and Cleaning Structural Steel, by F. H. Dill 1067
New Flash-Welding Techniques, by Chas. Bruno and G. W. Birdsall 1070
Power Supply for Automatic Resistance Welders, by T. F. Ellis 1079
Current Welding Literature 1079

practical welder and designer

Controlled Distortion—An Aid to Metal Working, by J. L. Morris 1080
Cam Plates, Pallets & Wedges 1083
Welding Old Iron Castings, by Rene D. Wasserman 1084
The Quickest and Cheapest Way to Make a Box Beam 1086
Hard-Facing vs. Wear, by W. C. Owens 1086
Arc-Welded Beam and Column Framing 1087

society and related events

Society News 1089
INDEX TO ADVERTISERS 1096
News of the Industry 1100
New Literature 1106
New Products 1109
List of New Members 1116
Section Activities 1118
Abstracts of Current Welding Patents 1125
Employment Service Bulletin 1126

welding research supplement

Cracking in Heavy Forged Flanges of Oil Separators, by H. B. Fergusson and P. L. J. Leder 521-s
Fractographic Structures in Weld Metal, by C. A. Zapffe and C. O. Worden 527-s
Development of Specimen Simulating Weld Heat-Affected Zones, by Ernest F. Nippes and Warren F. Savage 534-s
Fun, Facts and Fancies About Research, by K. W. Miller 546-s
"Transition" Temperatures Under Various Amounts of Plastic Flow, by N. Grossman and C. W. MacGregor 551-s
Cooling Rates in Arc Welds in 1/2-In. Plate, by Ernest F. Nippes, Lynn L. Merrill and Warren F. Savage 556-s
Relief of Residual Stress by a Single Fatigue Cycle, by W. P. Wallace and J. P. Frankel 565-s
Comparison of Radiation from Argon-Arc Welding with That of Metallic-Arc Welding, by E. van Someren and E. C. Rollason 566-s
The Statistical Part in Welding Investigations, Discussion by J. Manuele and Roscoe C. Byers, and Wade R. Weaver 567-s
Notch Sensitivity of Mild Steel Plates, Discussion by Perry R. Cassidy 568-s

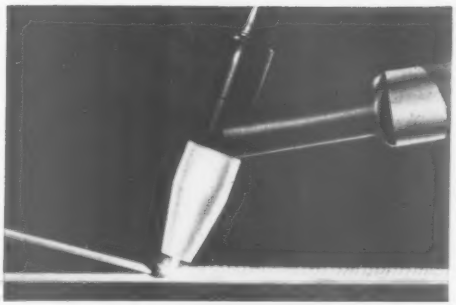
cover: Welding 1/4 in. mild steel plates for wire annealing furnace inner covers. Courtesy of The Canadian Bridge Co. Ltd.

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Advertising office, 400 Madison Avenue, New York 17, N. Y., Telephone: Plaza 3-4466. Subscriptions $5.00 per year in United States and possessions; foreign countries $7.00. Single copies, non-members $.75; special issues September and October $1.00; members .75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879.

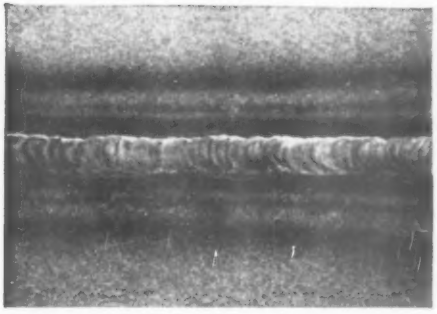
Copyright 1949, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided proper credit is given.

Weld Sheet Steel with the HELIARC torch

Trade-Mark



and wipe out one complete operation



AS WELDED — *This photograph, unretouched and natural size, shows that* HELIARC *welds in sheet steel are clean and uniform.*

There is no spatter or flux, so you save cleaning costs when you switch to the HELIARC process for welding sheet steel. And you keep the advantages of high speed, and minimum distortion that are characteristic of arc welding. Any manual arc or gas welding operator finds welding with a HELIARC torch easy to master.

Porosity-free welds in killed low-carbon steel up to $\frac{1}{8}$ in. thick can be made with this process. In non-killed grades, welds are as nearly gas free as can be produced by any welding process. Argon-shielding prevents pick-up of atmospheric gases. No argon is dissolved in the weld.

Joints welded with the HELIARC torch will not show under paint, lacquer, or even vitreous enamel finish. It takes only a light grinding to remove the low, smooth ripple and make the bead flush with the surface.

Get more information on this fast, clean, welding process from any LINDE office. Let us show you how it can improve your product and cut your costs. Just fill in the coupon.

The terms "Linde" and "Heliarc" are registered trade-marks of The Linde Air Products Company.

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities
In Canada:
DOMINION OXYGEN COMPANY, LIMITED, Toronto

THE LINDE AIR PRODUCTS COMPANY
30 East 42nd Street, New York 17, N. Y.
(or your nearest LINDE office)

Gentlemen: We would like more information on welding sheet steel with the HELIARC torch. We manufacture ..... (Product)
from ..... (Metal) of ..... (Thickness)
We are ☐ (are not ☐) now using inert gas-shielded welding

Name.....Position.....

Company.....

City.....State.....

VICTOR

REGULATORS for
- acetylene
- carbon dioxide
- compressed air
- hydrogen
- liquid pet. gases
- medical gases
- oxygen

TORCHES for
- air gas
- brazing
- bunsen burner
- descaling
- flame cutting
- flame hardening
- hand cutting
- heating
- lead burning
- machine cutting
- preheating
- soldering
- surface hardening
- welding

USE VICTOR STANDARD UNITS TO CUSTOM-BUILD Your Welding and Cutting Outfit

CYLINDER MANIFOLDS for
- all types of cylinder gases

CYLINDER TRUCKS

EMERGENCY FLAME CUTTING OUTFITS

WRITE us now for descriptive literature and name of nearest distributor.

Assembling your welding and cutting outfit is simple and low-cost if you start with one of VICTOR's basic units, such as the WC-1 shown here. WC-1 handles all ordinary welding jobs and cuts metal up to 10″ thick. For flame cutting, descaling, multi-flame heating or other special work, you add just the VICTOR tips, nozzles, or attachments which your job requires.

VICTOR makes welding and cutting equipment for all types of work, from fine jewelry manufacture, to cutting armor plate. Ask your nearest VICTOR distributor to help you custom-build the outfit best suited to your needs NOW.

VICTOR
FOR WELDING

NOW VICTOR hard-surfacing rod for every need.
See your VICTOR dealer.

VICTOR EQUIPMENT COMPANY
844 Folsom Street, San Francisco 7, California
3821 Santa Fe Avenue, Los Angeles 11, California
1312 W. Lake Street, Chicago 7, Illinois

The WELDING JOURNAL

volume 28 November 1949 number 11

Developments in Automatic Hard Facing

Fields of application of automatic hard facing are briefly covered and methods of operation indicated

by H. W. Sharp

AUTOMATIC electric welding, in extensive use for a good many years, has greatly widened the scope of welding. Until recently this process was applied primarily to the joining of steel parts in fabrication, using the conventional mild-steel and low-alloy welding wires in continuous coil form. Now, however, with the development of continuous high-alloy wires, the field of automatic welding has been enlarged to include hard-facing.

The automatic method has these distinct advantages: Completely uniform deposits are continuously welded at a much higher welding speed, welding efficiency is higher since no hard-facing alloy is lost in stub ends and deposits are far superior to the best manual welding. All these factors result, of course, in lower cost.

Experience has shown that the automatic application is readily adapted to practically any equipment or parts on which hard facing may be laid in a series of continuous stringer beads. This may be on a cylindrical piece where beads are placed circumferentially or on flat work where the deposit may be made as a series of straight stringer beads.

The fabricating process of making manual hard-facing alloys has been in use at Stoody Co., Whittier, Calif., for over 20 yr. and the product has been thoroughly proved and accepted by the welding trade. Automatic hard-facing wires are produced on special machines which form a continuous tube from mild-steel strip; the granular or powdered-alloying ingredients are added as the strip is being formed. This fabrication method permits the production of material of higher alloy content than is possible to obtain in a conventionally drawn wire, yet retaining sufficient flexibility for coiling and unreeling during automatic welding. Most automatic electric heads now on the market will handle the tubular hard-facing wires, or can by minor feed mechanism changes, be adapted to them.

Wire in tubular form permits an almost unlimited variety of alloys. Iron-base materials can be produced with alloy content as high as 60%.

Most of the hard-facing alloys now available as manual electrodes can be made for automatic application. One group of hard-facing wires is made with

Fig. 1 A set of rollers and idlers ready for reassembly on the tractor

The surface of these parts is sufficiently smooth in the as-welded condition to be entirely suitable. The welding time varies from 30 min. to 1 hr. each depending upon the extent of wear. The usual amount of alloy material is 4 to 6 lb. per roller and consists of 2 or 3 passes to bring the part up to original size

H. W. Sharp is Metallurgist, Stoody Co., Whittier, Calif.

Condensed from a paper presented at a meeting of the AMERICAN WELDING SOCIETY and the American Society for Metals at the Western Metal Congress, Los Angeles, Calif., April 1949.

alloy content varying between 5 and 10%. These materials have hardness values ranging from 35 to 55 Rockwell C hardness. Deposits of these materials possess good abrasion resistance in combination with impact strength and are low in cost. Another group of hard-facing wires includes those containing alloys from 10 to 35%. This group of materials can be made with a high-carbon content to provide excellent resistance to abrasion or they can be made with alloys which impart heat and corrosion resistance. Tungsten carbide tube-type material is also available for automatic electric application to parts subject to severe earth abrasion.

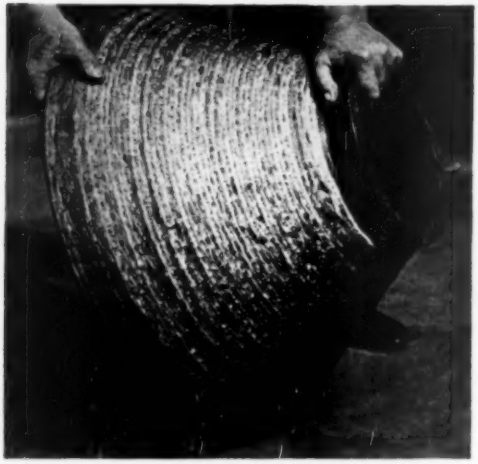


Fig. 2 A 2-ft. short head-crusher cone hard faced with 25 lb. of high-alloy automatic wire

This cone will crush an amount of rock equal to the full life of an unprotected cone before the 1/8-in. thick layer of hard metal is worn off

With automatic welding, manufacturers are able to produce longer wearing hard-faced parts uniformly and economically with the human element removed. At the present time there are a number of manufacturers using the process. Most notable are two of the major producers of tool joints for drill pipe. Several bands of tungsten carbide type material are applied in grooves; the welding time is a matter of 6 to 10 min. per joint, depending upon size, and the deposit is of better quality than can be produced by the normal manual method which would require up to 30 min.

One manufacturer of carrying-scraper units has standardized on automatically hard-faced blades for this equipment. Here a submerged-arc deposit of a medium-alloy material is applied at 800 amp. and a travel speed of 15-in. per minute, resulting in a bead nearly an inch wide. With the wear-resistant overlay a medium carbon-steel blade blank is suitable. Another concern producing coal augers has installed automatic equipment for welding the preformed flight to the shaft and follows the joining procedure with a bead of hard-facing applied to the outer edge of the flight with the same machine.

A growing number of privately owned job shops have set up automatic equipment for maintenance of construction equipment. There are now some 20 job shops equipped to handle the rebuilding of worn heavy equipment in the western states alone.

Fig. 3 A 4-ft. cone in the process of being hard-faced

This unit will require 250 lb. of hard metal before it is completed. Welding time will be approximately 24 hr., indicating a deposit rate of roughly 10 lb. per hour

The rebuilding of tractor rollers, manually welded for many years, was the first job shop work performed with automatic hard facing. Rollers are of such size and

Fig. 4 The mating bowl liner for the 4-ft. cone shown in Fig. 3

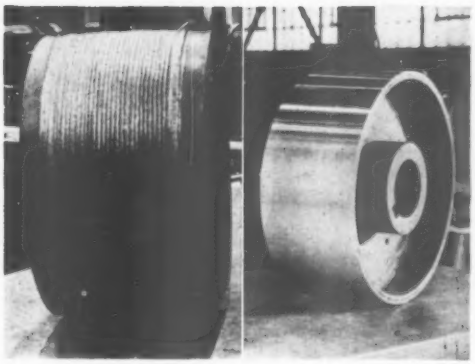


Figure 5 *Figure 6*

Figs. 5 and 6 A 24-in. mill brake drum hard faced and finish ground

Some of these brake drums have been in service for over 2 yrs., and the full life expectancy will be upward of 10 yr.

shape that they are handled easily for automatic rebuilding. Tractor rollers are rebuilt to full size for usually one-half the cost of replacement parts. The life of rebuilt rollers has been 2 to 4 times the life of factory-replacement parts. Naturally the alloy metal used for reclaiming rollers is the reason for the life extension. It has been proved that hard-faced rollers definitely cause less wear on track rails.

The possibilities offered by the automatic method of hard-facing are tremendous. The maker of equipment, parts of which are subjected to extreme wear, can at small cost add enormously to the service life of his product. Maintenance shops of large organizations such as heavy contractors, mines, steel mills and the like can profitably install automatic heads to take care of their equipment. Job shops located in areas where there is available sufficient business to provide a reasonable volume of similar wearing parts will find the automatic head a valuable addition in providing hard-facing service for local customers.

While the automatic method is yet in the test stages in many industries, the basic advantages are well proved in view of the results already achieved. Experimental work is constantly going forward and improvements in both alloy analysis and methods of application are continually being developed.

Industrial Use of Modified Armor-Plate Steel

Discussion by R. Alden Webster

It is gratifying to note the forward-thinking statements about, and the beginning of, a war-stimulated usage of armor steels in industry. Many uses will develop in which these heat-treated steels can be applied with satisfying reduction in weight and increase in pay loads and ranges as evidenced in this article on stripper-shovel design and construction.

It is interesting to note that yield strengths have been pushed up toward the 100,000-psi. mark and that the war-developed lime-covered electrodes have been the material consideration in this accomplishment. It is believed that higher-yield (from 100,000 to 120,000 psi.) steels may be incorporated now in these designs using the same electrodes, provided due care is exercised in locating the weld joints. These joints should be placed along lines of lower stress and not where the heavier stresses occur. Excellent results are thus obtainable when there is good preheat and postheat treatment together with interpass temperature control. The present research work is quite promising toward obtaining electrodes that will deposit weld metal capable of giving the desired high strengths. When this goal is obtained, the weld-joint location need not be given this attention in design.

A beneficial effect caused by the trend in the use of armor-type steels is that of keeping part of our steel industry in production of those steels that will help them to retain the knowledge needed for basic expansion should the time come again to dive into heavy armor purchasing. Also there is a material addition to the contracts let by the government for armor during peacetime, which condition enhances the work along lines which will be useful in armor production.

R. Alden Webster is Materials (Armor) Engineer with the Department of The Army, Office of the Chief of Ordnance, Washington, D. C.

This paper by A. F. Busick was published in the July 1949 issue of THE WELDING JOURNAL, pp. 651-658.

Limits of Welding Positions

It is often desirable from the standpoint of inspection, procedure, control or production planning that the dividing lines to distinguish between positions be established. A basis for standardization is offered in this article

by W. L. Warner

ON FIRST thought one might regard efforts to define limits for welding positions as not productive of much of practical value. In actual practice the welder must adjust his technique of depositing the weld metal to suit the position in which the weld must be made. As long as the finished weld is found to be satisfactory when inspected who cares what the welding position was? It is the finished job which counts most. For some purposes this sort of philosophy may be adequate.

It is true that in much industrial welding fabrication the weldment is positioned by suitable apparatus or setup such that welding can be performed in the true downhand or "flat" position for easiest deposition of the weld metal. For such applications of welding the definition of limits of welding positions are probably of little practical importance.

However, for the many instances where welding must be performed with the weldment *in situ*, or "as it lies," it becomes desirable to have some standard basis for decision as to whether each joint to be welded in the particular job at hand is in either the flat, the horizontal, the vertical or the overhead position when welding is to be performed. This is desirable from the standpoint of inspection, procedure control, or production planning and, in order that these decisions may be properly accomplished, it is essential that the limits or the dividing lines which distinguish between positions be established for reference purposes.

This sort of standardization becomes important when one considers the inspector's problem of applying welding procedure specifications or recorded procedures for welding joints to the fabrication of weldments. There is also the problem of classifying welding materials in accordance with accepted industrial standards. The question arises "Where does one position end and another begin?"

W. L. Warner is Senior Welding Engineer, Watertown Arsenal, Watertown Mass.

The suggestions of the Author are not to be taken as indicating the opinions or policies of the Ordnance Department.

This general subject was considered by the A.W.S. Committee on Definitions and Chart during the revision of the 1942 Nomenclature Standard. It was thought that delineation of the standard welding positions and their limits is more properly of concern to both the A.W.S. Committee on Standard Qualification Procedure and the A.W.S.-A.S.T.M. Committee on Filler Metal. Hence the A.W.S. Committee on Definitions and Chart attempted no revision of Figs. 1 and 1 (*A*) of the 1942 Nomenclature Standard.

In this discussion the writer makes several proposals regarding the establishment of limits for welding positions for the purpose of stimulating consideration of this subject. It is hoped that suggestions and ideas may be forthcoming which will be helpful to the A.W.S. Committee on Standard Qualification Procedure in its deliberations.

Attention is invited to a paper "The Definition of Welding Positions," by E. Flintham, published in THE WELDING JOURNAL for March 1949. The writer believes that this paper is the most comprehensive of any on this subject which have appeared in recent years. It proposes several interesting ideas which should be seriously considered and in addition presents the wide divergencies in the three major systems in use throughout the world today. This situation is of interest to all users of welding. All three systems discussed in that paper base "weld position" upon the location of two theoretical lines of the weld with reference to a theoretical horizontal and a theoretical vertical plane. In this one respect all three systems are alike.

In the American Standard only one of these theoretical weld lines, "Axis of a Weld," has been defined by the A.W.S. Committee on Definitions and Chart. In the Flintham paper this line is referred to as "Linear Axis." The other theoretical weld line, "Normal of a Weld," has not been defined by the A.W.S. Committee. It is suggested that this line, Normal of a Weld, could be defined as "the bisector of the angle between the groove faces perpendicular to the weld axis." This interpretation will apply to any groove or fillet weld as well as a bead weld or a weld bead, if necessary.

In Figs. 1 and 1 (*A*) of the 1942 Standard reference is

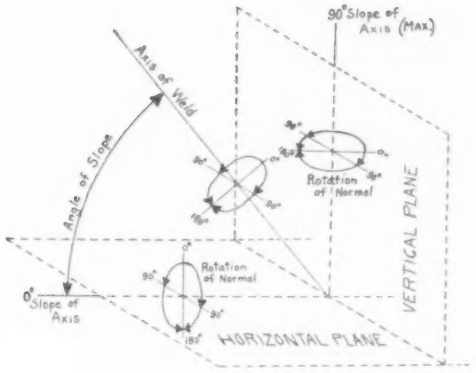

90° Slope of Axis (Max.)
Axis of Weld
Angle of Slope
Rotation of Normal
VERTICAL PLANE
0° Slope of Axis
Rotation of Normal
HORIZONTAL PLANE
Horizontal Plane lies always below Weld.
Slope measured from Horizontal toward Vertical Plane.
Normal of Weld bisects angle between groove faces.
0° Rotation of Normal points in direction of increasing Slope.
Rotation may be clockwise or counterclockwise (180° Max.)

Fig. 1 Weld position orientation

made to "Inclination of Axis" and "Rotation of Face" which in effect mean "Slope of Axis" and "Rotation of Normal," since a "Normal" is indicated by a black arrow in all sketches. It is, therefore, considered that all three systems are essentially alike in this respect, in that each makes use of a "Slope" or "Inclination" of the axis and a "Rotation" of the normal. It would appear, therefore, that the position of any weld could be very simply and clearly defined by giving specific values to weld slope and weld rotation.

The beginning of weld slope is the horizontal plane which means that zero slope has the weld axis either within or parallel to the horizontal plane. Thus all values of weld slope are measured from the horizontal plane and none can exceed 90° maximum. However, with reference to weld rotation there is disagreement between the three systems.

In Figs. 1 and 1 (*A*) of the 1942 American Standard the zero point for weld rotation is the 6 o'clock or 180° position. In both the British and Australian systems the zero point for weld rotation is the 12 o'clock position which is in the direction of increasing weld slope Which basis for specifying weld rotation is preferable? From the standpoint of uniformity the preference now appears to stand 2 to 1.

With reference to this particular point the writer quotes from the Flintham paper, "It is easier to imagine a butt weld in the true gravity welding position as having 0° rotation whereas in the American method this weld is defined as having 180°rotation." The writer agrees but would substitute "simpler" for "easier" in the quotation. Figure 1 illustrates the system proposed as a revision of the present American Standard. This method would make the basic principles of the three systems uniform which would appear desirable.

It will be noted also that in Fig. 1 weld rotation is measured either clockwise or counter-clockwise up to a maximum of 180°. This method is believed to be simpler than the present method which measures weld rotation in a clockwise direction through 360°, as shown by Fig. 1 and 1 (*A*) of the 1942 Standard.

With reference to the limits for the various weld positions the writer's suggestions are shown by Figs. 2 to 6 inclusive. In some respects these suggestions differ from the values established by the British and Australian systems and in others agreement is indicated.

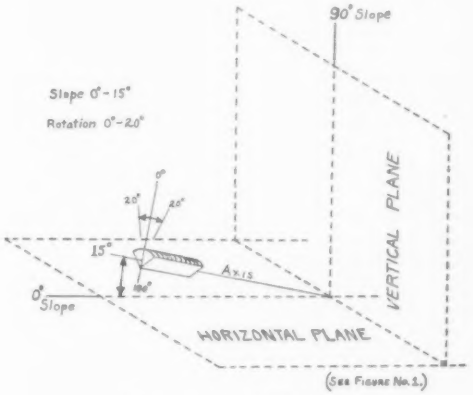


Fig. 2 Limits of flat position

Limits for the true gravity or flat position are suggested as shown by Fig. 2. These are the same as the 1942 Standard except that the proposed limit on weld rotation is 20 instead of 30°. It is thought that 30° rotation is slightly extreme for the true gravity flat position. This proposal agrees with the Australian system and is applicable to both groove and fillet welds.

Limits for the "horizontal" position are suggested as shown by Fig. 3. Here the maximum limit proposed for weld rotation is 90° for both groove and fillet welds. In the 1942 Standard, Figs. 1 and 1 (*A*), this limit is 100° for the groove weld and 55° for the fillet weld. This

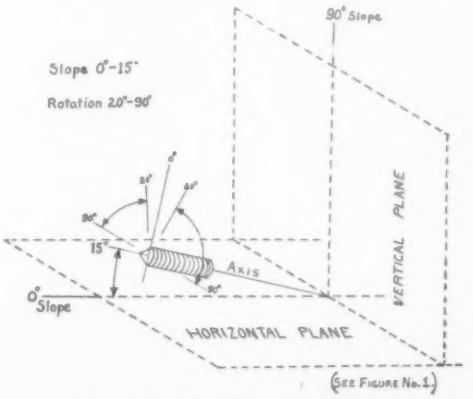


Fig. 3 Limits of horizontal position

limit of 90° on rotation is proposed because it is thought that the 55° limit for fillet welds is too restrictive and the 100° limit for groove welds is slightly within the range of the "overhead" position This limit of 90° on rotation is also proposed because it is impossible to visualize any fundamental difference between a single-V groove weld in a vertical plate and a fillet weld with 90° rotation With rotation exceeding 90° it is considered that certain aspects of the overhead position begin to appear.

Limits for an inclined position are suggested as shown by Fig. 4 This position is suggested to include the intermediate range between the truly flat and the truly vertical positions which, in the present American Standard, is included in the vertical position. To some extent this suggestion is a compromise and is proposed because it is considered that in this range welding technique partakes of a partly vertical and a partly horizontal aspect and is truly neither one. For purposes of qualification to cover this range of positions a vertical qualification should be required with the realization that some modification of technique for the inclined position may be desirable, particularly in the range of the lesser slope.

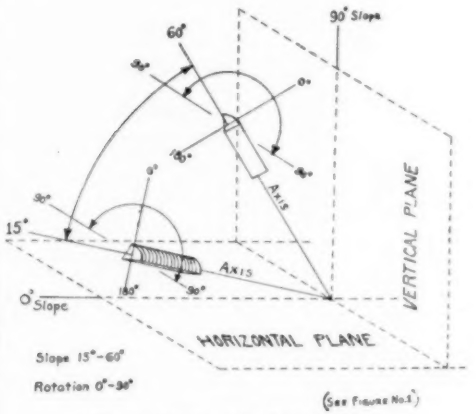


Fig. 4 Limits of inclined position

The limit on weld slope has been suggested as 60 instead of 80° with the thought that between 60 and 80° a 360° weld rotation can be considered to require as much of vertical technique as does the 360° weld rotation with weld slope between 80 and 90°. It is recognized that some aspects of overhead technique may be considered to appear in this range of 60 to 80° weld slope with 360° weld rotation but it is thought that requirements for vertical technique would predominate in this range. Incidentally this 60° limit on weld slope has been selected as a compromise between the British and Australian systems. The limit on weld rotation has been set at 90° in either direction as compared to 100° for groove welds and 55° for fillet welds in the 1942 Standard.

Limits for the vertical position are suggested as

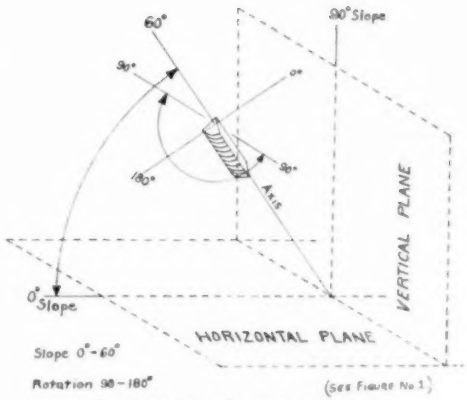


Fig. 5 Limits of overhead position

shown by Fig. 6. These limits are conditioned by the suggestions for the inclined position shown by Fig. 4 and involve 360° weld rotation throughout, except that weld rotation is considered to be in either direction up to a maximum of 180°.

Limits for the overhead position are suggested as shown by Fig. 5. These limits are conditioned by the limits for positions already proposed and cover the space remaining in the position quadrant.

It is desired to point out that by this proposed system the standard positions for qualification may be easily and simply prescribed as follows:

Position qualified	Weld	Slope, °	Rotation, °
Flat	Groove	0	0
	Fillet	0	0
Horizontal	Groove	0	90
	Fillet	0	45
Vertical	Groove	90	0–180
	Fillet	90	0–180
Overhead	Groove	0	180
	Fillet	0	180

NOTE: Tolerance ±5°.

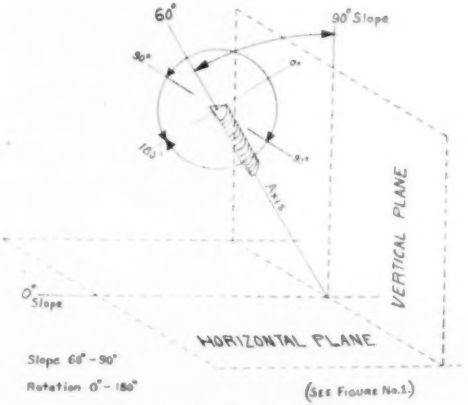


Fig. 6 Limits of vertical position

Oxyacetylene Flame Hardening in Commercial Heat Treatment

Range of materials which may be flame hardened is briefly reviewed as is also the various flame-hardening methods. Typical applications are shown

by J. T. Howat

THE oxyacetylene flame-hardening process has earned an established place among modern production methods. Its position is the more outstanding and more readily understood when certain elementary facts about the moving parts of modern mechanisms and machines are kept in mind.

When we consider the problems of wear and failures in machinery, we find that the bulk of such difficulties arises in moving parts. We further find that wear is the primary failure in these moving parts—gears, cams, shafts, sprockets, sleeves, pinions, wheels, ways, tracks and guide faces. Finally, in considering the design and construction of such parts, we realize that the contact or wearing surfaces comprise only a small proportion of the total surface area of the part, and only a far smaller proportion of the mass of part. Further, however, these parts are subject to other service effects than wear. They must stand tension, torsion, compression, impact, bending and vibration, and in many cases corrosive actions as well.

We can meet these varying conditions by producing an assembly that will have a more or less uniform resistance to them in all its parts according to their various individual requirements, by breaking down the assembly part by part, and using a variety of special materials for each part. Such components, when assembled in a complete unit, present good over-all resistance to all service conditions. This procedure, however, rapidly becomes uneconomical under present-day competitive conditions. The more practical approach in very many cases is the special treatment of what might be termed general-purpose materials to provide a good degree of special qualities in the part. In our industrial scheme of things, steel is the basic material; and under proper treatment, a relatively few analyses of steel can provide wide ranges of characteristics.

J. T. Howat is President, Pittsburgh Metal Processing Co., Inc., Pittsburgh, Pa.

This paper was presented before the Annual Meeting of the International Acetylene Association, Pittsburgh, Pa., April 25–26, 1949.

In the replacement of failed parts, we find two general reasons for failure. One is wear, the contact surfaces failing because of insufficient hardness, overloading or lack of lubrication. The other reason is fracture resulting from fatigue, poor design, lack of suitable strength in the material or residual stresses.

The question of strength cannot be considered merely a function of tensile properties, which are the usual criterion, but must be regarded as the ability of a part to meet its service requirements. Thus, the ultimate strength for one part will be toughness, ductility to meet flexing or twisting loads; for another, extreme hardness to meet sliding abrasion; for a third, tensile strength alone. This factor is further complicated by the desirability, in some parts, of combining two or more kinds of strength in the same part. The outstanding common instance of this is in gears where a high hardness is desirable on the wearing faces of the teeth with a tough ductile core in the teeth and body of the gear to stand the power loads. In such a case, and in many others, the normal character of steel provides the desired quality in the mass, and the major task is proper preparation of the wearing surfaces.

With the demand for more compact equipment of steadily increasing load capacity, the need to prepare these contact surfaces has been of growing vital importance. The job can be done with any of the following processes: Standard full quench heat treatment; localized case hardening; nitriding, chapmanizing; induction hardening; hard facing; hard chrome plating; metallizing or flame hardening.

These processes, except for flame hardening and hard facing, require considerable large and expensive equipment, a large floor space and a decided time element in processing. Except for induction and flame-hardening methods, the heat-treating department in most plants is usually a bottleneck in the production line.

When the production demand will warrant the investment required for induction equipment, it is very satisfactory; but for economy, flexibility and speed, no other process can handle the variety of work with the success that flame hardening does today.

Table 1—Oxyacetylene Flame-Hardening Costs

*Approximate depth of hardness penetration in in.**	*Torch Travel speed per min. in in.*	*4-in. tip coverage, sq. in. per min.*	*Cu. ft. acetylene consumption per sq. in. of surface†*	*Cu. ft. oxygen consumption per sq. in. of surface†*
5/16	2	8	0.55+	0.61−
1/4	3	12	0.37−	0.40+
3/16	4	16	0.28−	0.30+
1/8	5	20	0.22+	0.24+
1/16	6	24	0.18+	0.20+

* Depths subject to variation with the thickness of the object heated.

† Based on using 4-in. wide tip. If a 3-in. wide tip is used, add 10% to gas consumption. If a 2-in. wide tip is used, add 15% to gas consumption. If a 1-in. wide tip is used, add 20% to gas consumption. Other sizes proportionately.

When, in 1925, we first started flame hardening, we were using standard 1 and 2 flame tips. Soon, we found a need for water-cooled equipment to meet the demand for hardening large areas, and the successful results obtained with the process created a steady natural demand for more elaborate equipment. Today, there are on the market several machines to do fully automatic, mass-production flame-hardening; and in most large steel mills, and in gear, machine and maintenance plants, there is a well-equipped flame-hardening department.

Flame hardening is also an essential department of the fully equipped commercial heat-treating company. For the small or average machine shop there is an important question of whether or not they should establish their own heat treating for flame-hardening operations. The cost of equipment for such a flame-hardening setup is not great. A standard torch, a few tips, a standard portable-type cutting machine and a discarded lathe or drill press will provide for a wide variety of flame-hardening work. On the other hand, we should not overlook the fact that success with this process depends to a large extent on the operator's skill, unless an expensive automatic machine is employed.

It requires many, many weeks of training of an operator to insure consistent, uniform results. There should be competent metallurgical personnel to insure correct decisions on materials and treatments. There should be an assured steady volume of work for the operator, so that once he has been successfully trained he can keep in practice and stay specialized in this highly specialized work. As the color of the heated surface is the only guide for judging the temperature of the material, shop lighting conditions must be adapted to suit. They should always be the same, with uniform lighting and slightly shaded for preference, as excess brightness, such as sunlight, can lead to overheating and burning of the steel.

These, and other considerations, must be kept in mind in planning for a flame-hardening operation, and they tend to discourage any but a full-fledged production arrangement. On the whole, this is as it should be, for heat treating, by any means, is something of an art; and it is a good guiding principle to leave it in the hands of experts, either in your own shop or a commercial heat-treating establishment.

With any flame-hardening setup, the procedure questions tend to start with a choice of fuel gases. Two factors govern this choice—economy and the quality of the results. Low-pressure natural gas and liquid petroleum gases have too low a flame temperature for flame hardening. Natural gas under high pressure with suitable burners, and oxygen, sometimes with propane added, have been used. A very satisfactory flame-hardening job can be done with hydrogen and oxygen. Generally, however, acetylene is the nearest thing to an ideal fuel gas for flame hardening, and its use is so well founded that we can accept it as the basic fuel gas for the process.

Acetylene, burned with oxygen, provides the highest commercially available flame temperature, and along with that characteristic, it also provides the best controllability, not only in establishing suitable flame characteristics, but in duplicating them as often as required. Commercial acetylene is consistently pure and reliable, readily available, and with its uniformity, predictability and operating characteristics, provides the most practical and economic means of doing most flame-hardening work. Generally, we use acetylene at 15 psi. in proportion of 1 to 1.1 cu. ft. of oxygen at 14 psi. in a neutral flame. Increase of oxygen pressure results in danger of overheating with subsequent sweating of the surface.

As in all processes, one of the primary questions is cost. There are several factors that control the cost of heat treating with oxyacetylene flame, some of which differ from factors involved in other methods. They include: depth of hardness required; ratio of treated

Table 2—Typical Physicals After Flame Hardening

C	*Mn*	*Cr*	*Ni*	*Mo*	*Elastic limit, psi.*	*Tensile strength, psi.*	*Izod impact, ft.-lb.*	*Brinell on core*	*Brinell on surface*
0.18	0.47	..	1.64	0.24	105,000	120,000	62	250	477
0.33	0.62	0.64	1.52	..	110,000	130,000	75	..	534
0.34	0.61	..	1.75	0.25	175,000	185,000	35	..	555
0.35	0.68	0.93	..	0.21	160,000	130,000	65	..	627
0.36	1.92	..	..	..	115,000	124,700	60	255	415
0.42	0.56	0.83	..	..	135,000	150,000	48	325	495
0.42	0.69	0.97	..	0.18	130,000	147,000	40	350	514
0.42	0.83	..	..	..	75,000	105,000	27	..	514
0.43	0.57	..	3.60	..	125,000	135,000	69	..	678
0.47	0.68	..	..	..	85,000	115,000	..	258	541

Table 3—Alloy Cast Irons

Classifications	Analysis T.C.	Gr.C.	C.C.	Mn	Si	Cr	Ni	Mo	Brinell hardness* Before flame hardening	After water quenching
Nickel	3.46	2.78	0.68	0.71	1.28	..	1.08	..	215	507
Nickel	3.13	..	..	0.86	1.84	..	1.43	..	..	514
Nickel	2.84	..	..	0.91	1.42	..	1.47	..	..	495
Nickel	3.24	..	..	0.57	1.19	..	1.50	..	..	514
Nickel	3.22	..	..	0.67	1.76	..	1.61	..	..	514
Nickel-chromium	3.01	2.60	0.41	0.79	2.21	0.42	1.07	..	..	470
Nickel-chromium	2.95	..	..	0.81	1.67	0.33	1.28	..	..	514
Nickel-chromium	2.87	..	..	0.85	1.66	0.29	1.57	..	217	650
Chromium-molybdenum	3.19	2.50	0.69	0.76	1.70	0.03	..	0.01	217	436
Chromium-molybdenum	3.19	2.57	0.62	0.81	2.28	0.37	..	0.23	187	525
Chromium-molybdenum	2.85	2.26	0.59	0.76	2.04	0.29	..	0.30	192	555
Chromium-molybdenum	3.22	2.57	0.65	0.75	1.73	0.03	..	0.47	223	555
Chromium-molybdenum	3.20	2.62	0.58	0.64	1.76	0.01	Trace	0.48	223	578
Nickel-chrome-moly	3.00	..	..	0.75	2.25	0.20	0.20	0.35	225	540
Nickel-chrome-moly	3.36	2.75	0.61	0.74	1.96	0.35	0.52	0.47	235	524
Nickel-chrome-moly	3.21	2.61	0.60	0.67	2.24	0.50	0.06	0.52	235	534
Nickel-chrome-moly	3.22	2.69	0.53	0.66	2.02	0.02	1.21	0.52	241	524

* Hardnesses as shown are not indicative of maximum hardness obtainable but are representative of flame-hardening results using varying quenching rates to meet specific hardness specifications.

area to total mass; analysis of the steel used; cost of oxygen and acetylene production (i.e.) single cylinders, manifolds or generated acetylene; method of working—hand or machine and type of tip and speed of torch travel.

The data on Table 1 will give an idea of gas consumption to be expected and, of course, we must add to this the cost of labor and setting up for the job. Generally, a comparison with other methods of accomplishing similar results on suitable work pieces will show that flame hardening is the most economical way to operate. In other cases, where economy may not show up so well, we may find it cheaper in the long run because of superior character or quality of the results.

In these latter cases particularly, we find flame hardening advantageous because of its high degree of controllability. We can control very precisely the depth and area of the hardened surface, heat treating only the exact sections of the part which require it. Large and complex parts can sometimes be heat treated by other methods after great difficulty and expense, whereas with the torch it becomes a relatively simple and inexpensive procedure. In any case, flame hardening comes very close to meeting the ideal in parts which must provide very hard-wearing surfaces on a tough ductile body with a good transition zone to the body of the part which retains maximum strength for loading in service.

Naturally, the resulting physicals in both hardening and unhardened zones will vary with the basic analysis of the material (Table 2), and the question of what materials can be flame hardened is very important. We can safely say that all steels and irons that are hardened by furnace processing can also be flame hardened. The straight carbon steels of S.A.E. 1035 to 1050 are most commonly used; next, the pearlitic steels and medium-alloy steels; and finally the regular high-alloy steels. With the high-alloy steels, we must use the same precautions we would need in ordinary furnace heat treating. That is, when we raise the alloy content over 1.75%, we should preheat the steel slightly. In actual practice, a saving of 20% in time can be made by preheating not only high alloy but all work before flame hardening.

The degree of quenching must be determined according to the design and analysis of the part. For maximum quench of some items, a water pressure of 60–100 lb. will be used—in other cases, the quench is reduced to a fine air-water spray, or even soluble oil or still air. The work should never be quenched to dead cold, and a drawing treatment should be given where possible. A residual temperature of around 300° F. should be left in all work. The depth of hardness at all corners

Table 4—Mechanite Irons

Analysis T.C.	Gr.C.	C.C.	Mn	Si	Cr	Ni	Brinell hardness* Before flame hardening	After water quenching
2.65	0.56	2.09	0.63	1.01	0.24	..	367	518
2.77	2.08	0.69	0.91	1.82	0.10	0.16	253	472
2.88	1.92	0.96	0.72	1.42	0.11	Trace	350	560
2.94	2.30	0.64	0.84	1.58	0.08	0.07	292	450
3.10	2.61	0.49	0.67	1.91	0.06	..	241	472

* Hardnesses as shown are not indicative of maximum hardness obtainable but are representative of flame-hardening results using varying quenching rates to meet specific hardness specifications.

Table 5—Pearlitic Malleable Irons

Analysis T.C.	Gr.C.	C.C.	Mn	Si	Brinell hardness,* After water quenching
2.30	1.80	0.50	0.95	0.98	401
2.65	2.15	0.50	0.40	1.25	525

* Hardnesses as shown are not indicative of maximum hardness obtainable but are representative of flame-hardening results using varying quenching rates to meet specific hardness specifications.

Fig. 1 Portable-type cutting machine, carrying special flame-hardening and tempering fixture, hardening and tempering open-hearth steel rails. Rails almost completely submerged in water tank to hold down distortion risk

should be reduced to eliminate cracking, and to prevent overheating of the work, we must avoid too vigorous heating or having the tip too close to the surface. This distance may vary from $^1/_8$ to $^1/_2$ in., depending on the material, the design and the depth of hardness desired. If extra depth is required—say more than about $^3/_{16}$ in.—it is best to pull the tip slightly further away from the surface, but not more than $^1/_2$ in. This allows time for deeper penetration of the heat without overheating of the surface metal.

Since, in flame hardening, we are applying a very high-temperature heat source to a concentrated local area, the nature of the process leaves us open to several typical heat-treating defects unless proper measures are taken to prevent them.

As previously stated, competent metallurgical control should be maintained as closely as possible over the flame-hardening department, just as it would be for any

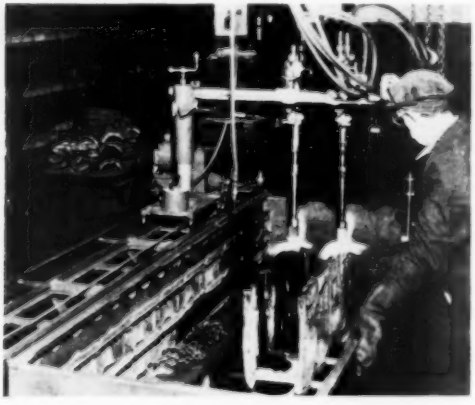


Fig. 2 Flame hardening two parallel surfaces of locomotive spring saddle, using two torches

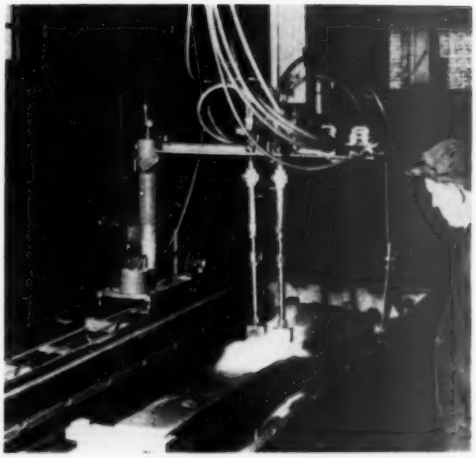


Fig. 3 Flame hardening the faces of a locomotive bar guide with two parallel torches to cover full width in one pass

Fig. 4 Flame hardening front surface of milling machine bed ways. Workpiece mounted on a welding positioner, torch on a portable-type cutting machine

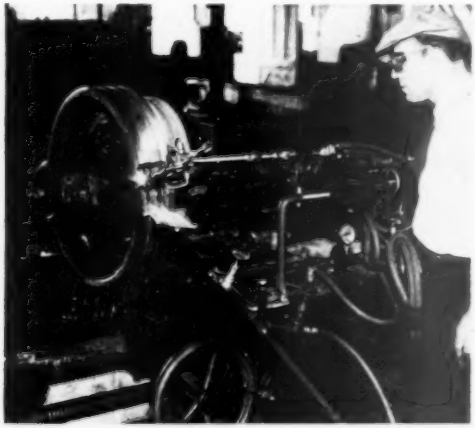


Fig. 5 Rotary operation, with special multiflame groove-hardening tip, on the walls of grooves in a piston head ring

other heat-treating operation. The operator must be adequately trained and experienced; he must be provided with suitable working and lighting conditions and proper eye protection and other safety measures. He must also be acquainted with the grade of material in the work and the results required, so that he can judge his color and temperature and quenching to obtain the best results.

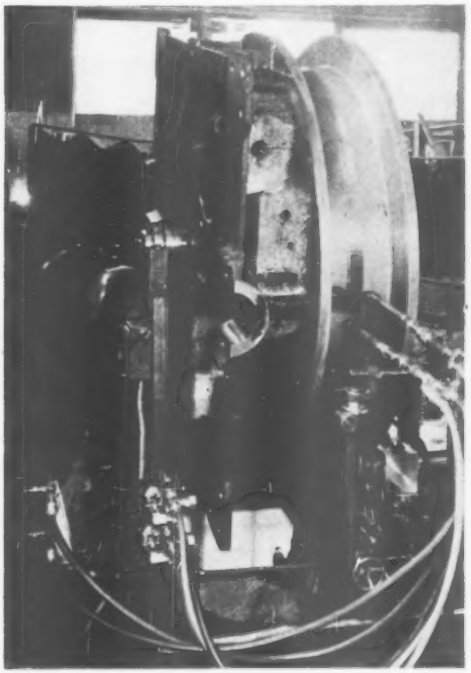


Fig. 6 Flame hardening roller pads on lower frame casting for a steam shovel. View of torch setup and rotating jig

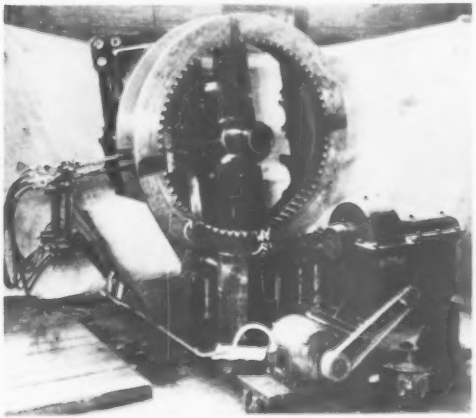


Fig. 7 Side view of the operation shown in Fig. 6. Part is rotated by 3 hp., 1200 rpm. motor through a 1600–1 gear reduction unit with chain and belt drives to obtain suitable slow speed for flame hardening

The grain structure of the steel will also affect the results. It is always preferable to use fine-grained steels, as their inherent resistance to grain growth in overheating is an advantage as well as their shallow-hardening characteristics which are often desirable. With coarse-grained steels, if the surface becomes overheated by the flame, we may cause further enlarging of the grains resulting in possible surface checking of the metal. Improper analysis of metal, as well as overquenching, will also produce surface checks.

Where the thickness of the areas being hardened varies, or when we reach a sharp corner, we must regulate the heating and quenching to reduce the hardness in depth or degree in proportion to the thickness of the metal.

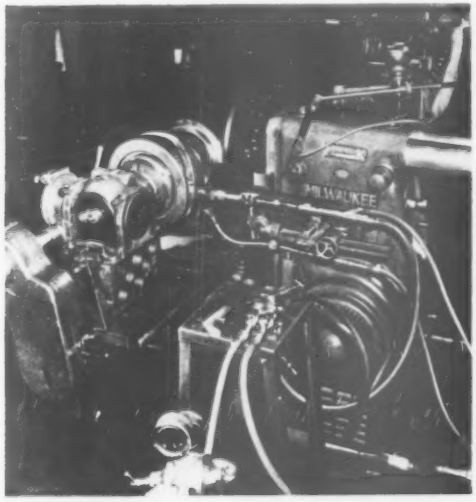


Fig. 8 Flame hardening the groove of a barrel cam on a horizontal milling machine with a special groove-hardening tip

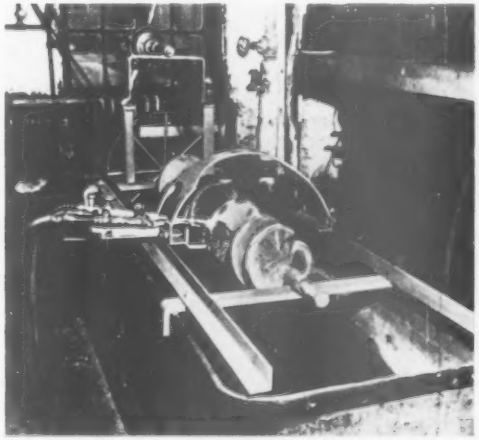


Fig. 9 Stoker elevator screw flame hardened along edge of flight. Flames are moved along the part by rotation of the screw against contact bar on the torch carriage

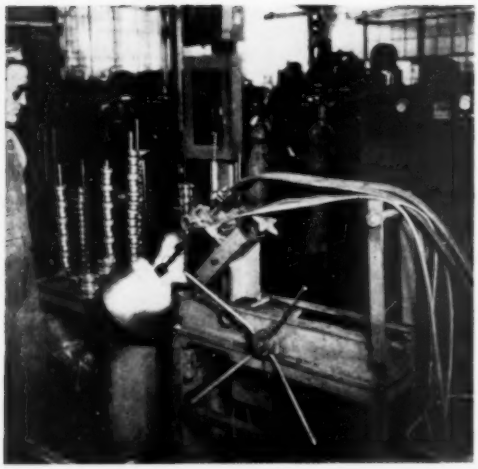


Fig. 10 Gear flame-hardening machine, using spinning method for small gears in mass production

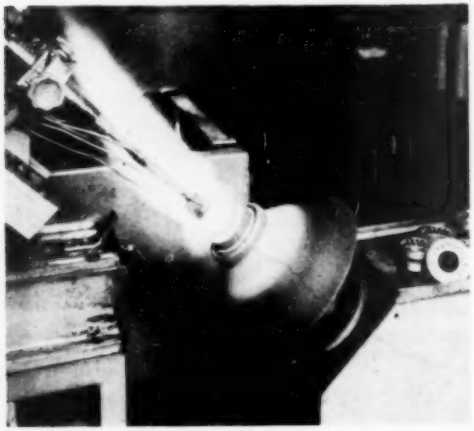


Fig. 11 Clutch gear teeth being flame hardened by spinning method on machine seen in Fig. 10

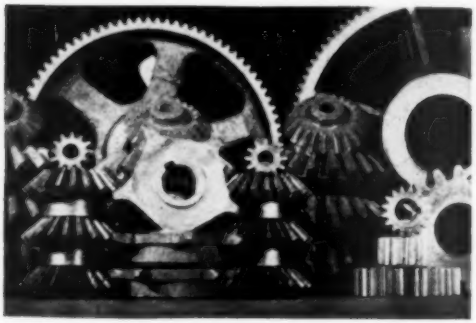


Fig. 12 A collection of some of the types of gears flame hardened as routine production of the commercial heat-treating shop

In most flame-hardening applications, the area being heated and quenched is a very small portion of the total mass. This, combined with the fact that the amount of Btu. which have been imparted to the steel, and which must be removed to get full quench, are kept to a minimum means we obtain the maximum possible hardness from a given analysis of steel or iron in the treated area.

Fig. 13 Flame hardening of a bevel ring gear on a gear flame-hardening machine

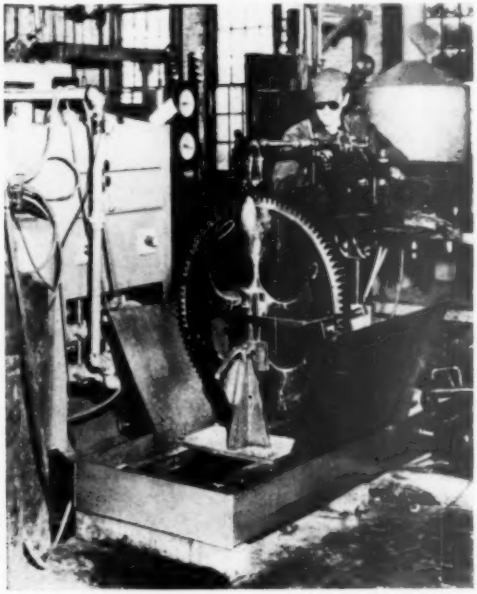


Fig. 14 Flame hardening the teeth of a large spur gear, with torch and gear flame-hardening yoke and tips mounted on a portable-type cutting machine

The great difference between furnace and flame-heated work, in the amount of heat to be dispersed by quenching of the piece, is one reason for the success of the flame-hardening process. In many cases, with furnace treatment, it has been necessary to use alloy steels to obtain the necessary hardness on items where shape or design would not permit a vigorous or full quench for full surface hardness in plain steels. With flame hardening, such parts can be made of plain carbon steels giving the necessary hardness without the dangers involved in fully quenched work. Flame hardening, in such cases, will yield surface hardness values ranging 100–150 points Brinell higher than permissible with fully quenched work, and such flame-hardening operations are now standard practice.

When core physicals have to be higher than those of annealed carbon steels, however, alloy additions are used. The steel may be heat treated in the rough by normalizing or liquid quenching to the machining range of 250–350 Brinell, and after machining, the required

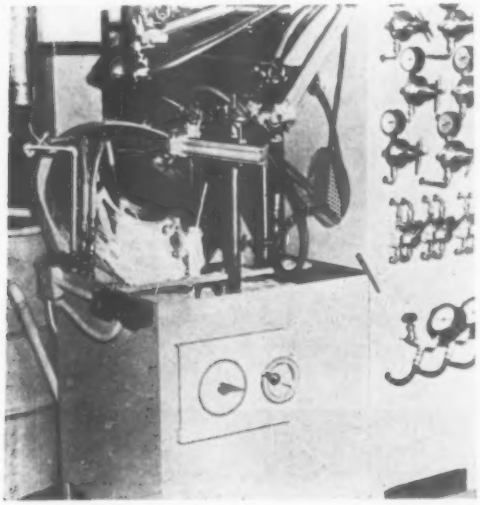


Fig. 15 General view of a special machine built for production flame hardening of precision dies

Fig. 16 Close-up of the die-hardening operation on the special machine shown in Fig. 15. Note soluble oil quench

Fig. 17 Flame-hardening a 4-in. diameter shaft in a vertical flame-hardening machine equipped with annular tip assembly

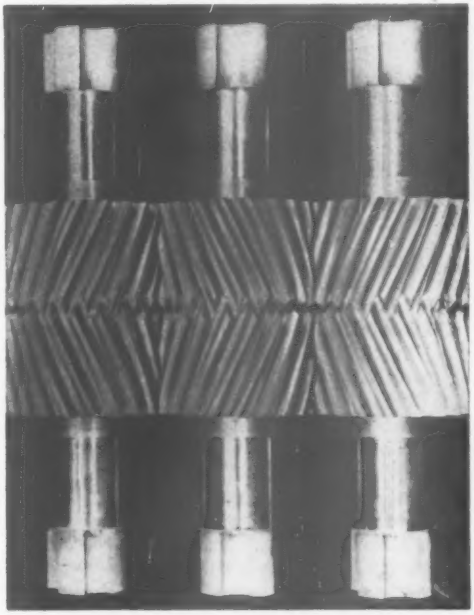


Fig. 18 Herringbone mill drive pinions. Teeth and wabblers flame hardened after complete machining and grinding of necks

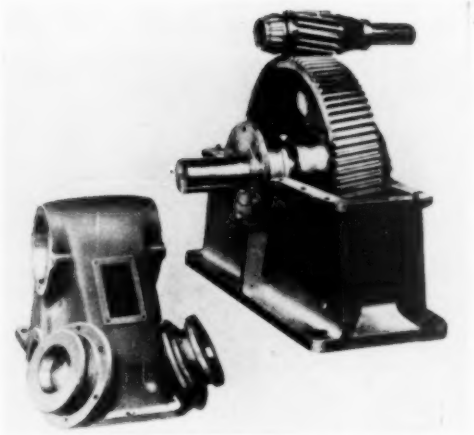


Fig. 19 Single reduction helical gear drive with flame-hardened teeth

surfaces are flame hardened. This gives a combination of very desirable physical values—a combination scarcely obtainable by any other process—and with flame hardening we find failures from heat treating reduced to an absolute minimum. When parts are made of cast steels, and hardening is required on unmachined surfaces, we usually find some decarburization of the skin. To permit flame hardening of such unmachined parts, the carbon range of the casting steel should be raised ten points which will readily yield hardness of 450–550 Brinell.

For machined surfaces, the carbon range should be the same as for wrought steels, and the use of alloy steels should be governed in the same manner as for wrought materials.

When physical requirements are not high, or for economy production, cast iron may be used for many parts. Again increasing the wear resistance of the material is desirable; and to make this possible, we have to use what are termed pearlitic irons. These have a composition of combined carbon of 0.60–0.80% plus other definite chemical combinations. A low silicon with a maximum total carbon of not more than 3.25% will give a surface hardness of about 600 Brinell.

Additions of chromium, manganese, nickel, molybdenum and vanadium all refine the grain size of the irons and help to increase the hardening results. Table 3 gives several typical alloy cast iron compositions and the hardnesses obtained. Table 4 gives similar data for the Meehanite irons. These commercial irons are of the sorbo-pearlitic class that hardens to 400–500 Brinell very successfully.

With the malleable irons, we get our best results on a machined surface, as the cast surface has a considerable depth of decarburized metal which will only harden when enough time of heating is given to diffuse the temper carbon through this zone. Table 5 shows two typical compositions and the hardness results obtained by flame hardening.

In general terms, then, we find that flame hardening can be successfully applied: to all hardenable steels and irons; with good economy according to the job; to produce maximum hardness for the material and over accurately controlled areas to accurately controlled depths, and that the work, to be successful, requires that we provide suitable hardening, materials and operating procedures.

There are few reasons for failure with an adequately planned and supervised flame-hardening department and every reason to expect success with the operation. The process is applicable to almost any surface to which the tip of an oxyacetylene torch can reach by one of the four basic methods of application. These basic methods—each of which has several variations—include: spot method, unit area method, progressive method and spinning method.

Equipment for applying the process may be very simple or very elaborate. For mass-production high-capacity requirements, we use what amounts to flame-hardening machine tools. For commercial work standard parts are combined to provide the least complicated, most readily adaptable type of setup. Thus, a portable-type cutting machine carrying the torch and quench will cope with the greater proportion of straight-line work; a lathe and a fixed torch will handle much circular work; and a variety of simple fixtures will accommodate more complex operations. Flame hardening is mechanically such a straightforward operation that it is seldom necessary to go in for complicated means of applying it.

Probably the simplest application of flame hardening, as a production job, is that illustrated in Fig. 1. The part, a rail, is immersed in a tank of water to hold down the risk of distortion, and a portable-type cutting

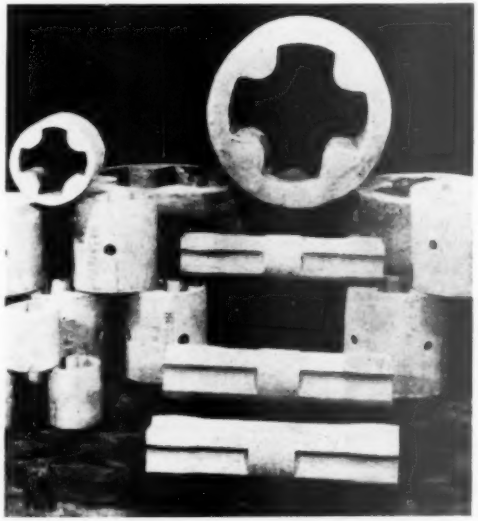


Fig. 20 A group of rolling mill coupling boxes and spindles normalized and with wearing surfaces flame hardened

Fig. 21 A 24-ft., 10-in. diameter tin mill spindle, and a combination sleeve spindle, both flame hardened

machine on a parallel track carries the torch and the quench in a straight line down the work. Figure 2 shows the further development of this type of operation with a special unit to hold and carry two torches and two quenches for simultaneous hardening of two separate surfaces. In Fig. 4, we again have a straight-line cutting machine setup, with the operation carried out in the horizontal plane by addition of a standard bevel attachment to the torch. Most such narrow, flat surfaces can be flame hardened with such simple equipment. As parts become wider, we may find it necessary to extend the width of the tips, use two torches side by side, as in Fig. 3, or to harden in progressive bands or strips, but the basic setup remains about the same.

When the part is circular or cylindrical, the simplest procedure very often is rotation of the part rather than movement of the tips. Figure 5 demonstrates the application of this method to a rather unusual job, flame hardening the walls of the grooves in a piston head ring, by rotating the work between lathe centers. In this job, a special multiflame tip is required for efficiency and best results.

Even when the workpiece is of enormous proportions, as shown in Fig. 6, flame hardening is still a relatively simple operation. This is a cast steel lower frame for steam shovel, weighing 3400 lb., on which the roller pads are hardened. Both faces of each pad are done 4 in. wide and with 57½ in. mean diameter—a total area of 1440 sq. in. on each pad, to $^{3}/_{32}$ in. depth. The size of this part, and location of the hardened areas, would all but prohibit hardening by any other means, yet provision of a rotating positioner and a suitable torch setup makes flame hardening to full hardness a routine operation. A more complete view of the equipment for this operation appears in Fig. 7.

Some parts, by their design, remove themselves from the straight line or plain rotary type of operation, requiring spiraling or other bi-directional movement. Such cases are the parts illustrated in Figs. 8 and 9. In Fig. 8, a barrel cam groove, hardened with a special groove-hardening tip, is mounted on a horizontal milling machine which provides the necessary rotating and lateral movement. In Fig. 9, a locomotive stoker-feed screw acts as its own drive mechanism to move the torch laterally as the part rotates. An arm contacts the flight ahead of the torch so that the flames are moved by the screw itself.

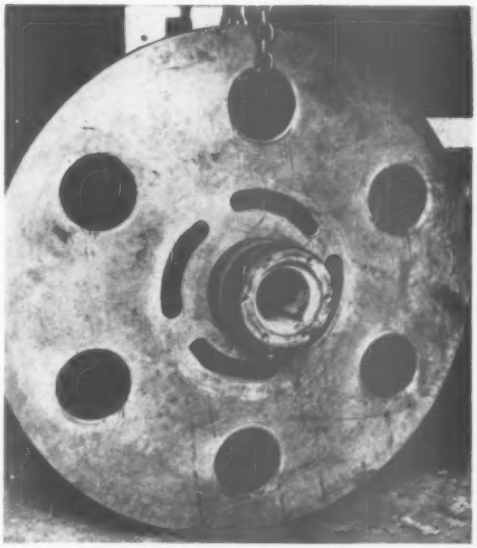


Fig. 23 A wire spool, with 4-in. collar of the hub and flange flame hardened

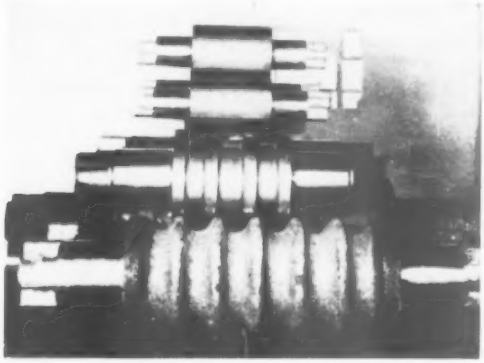


Fig. 22 A variety of mill rolls, various working parts of which have been flame hardened

Figures 10 and 11 demonstrate a spinning type of operation on circular parts. Where the part is of small size, and general surface hardness is desired, this method is readily applicable. In this case, the equipment being used was designed for a relatively rapid mass-production type of operation, but the spinning method is by no means restricted to that category of work.

Gears are among the parts which gain most from the peculiar usefulness of flame hardening. Figure 12 gives some idea of the variety of such parts which can be, and are, flame hardened as routine production operations. Gears are hardened by either of two basic methods. Where teeth are small and closely spaced,

as on the bevel ring gear in Fig. 13, they may be done by simple rotation under the torch, much as if they were flat surfaces. Where teeth are larger, they are hardened individually, as on the large spur gear in Fig. 14. In this case, a portable-type cutting machine, with track at right angles to the plane of the gear wheel, but parallel to the faces of the teeth, carries the torches in and out over each tooth to harden the faces over the required contact areas to suitable depth.

Flame hardening is also applied to such precision parts as dies, as illustrated in Figs. 15 and 16. For this operation, a specialized production job, a flame-hardening machine was built and used. An even more highly specialized machine is shown in Fig. 17, for mass-production hardening of 4-in. diameter shafts. In this machine, a specially designed and built circular tip is used for straight-line hardening of the shaft in a vertical position. The part could, if production did not warrant special equipment, be hardened by the same basic method used in Figs. 5 and 6, either by treating successive bands, or by spiral progressive treating or by spinning.

By varying the application on such lines as these, it is possible to apply flame hardening to almost any part. Figures 18 through 23 illustrate something of the range of parts which pass through the flame-hardening department in a commercial heat-treating shop as routine production. All these, and many others gain from the fundamental values of flame hardening by use of the most economical material, giving maximum strength and wearing capacities, to deliver the longest and most satisfactory service life with an absolute minimum of failures at the most economical production cost. It is because flame hardening makes this combination of advantages possible that the process is a standard production method in modern industry.

Oxygen-Acetylene Scarfing in the Steel Mill

Current practices in surface conditioning of steel are described and procedures for conditioning various steel products by scarfing are indicated

by George Mersot

FLAME deseaming of blooms, billets and slabs, commonly called scarfing, is one of the late developments that is helping the steel industry overcome surface-conditioning handicaps. The users of steel are finding new uses for our product and surface requirements are becoming more severe with each new development.

Years ago the only method we had for conditioning steel surfaces was by hand chipping. This practice is still in use but is fast becoming a lost art. Chipping is done with a pneumatic hammer that weighs about 13½ lb. It is fitted with a chisel that weighs about 1 lb. When new, the air pressure required to efficiently operate the tool is about 90 psi. The rapidly moving piston of the hammer striking the chisel causes a vibration the chipper absorbs as each cut is made. Fatigue develops early in the course of a man's working day. Because of the weight of tools carried by the chipper, the vibration he absorbs in a bent-over position, and the fatigue strain, it is easy to see why chipping is no longer a desirable occupation.

As far back as the year 1928 it was apparent that other means would be needed for deseaming steel surfaces.

In 1930 the idea of surface-conditioning of rerolling and forging grades by the use of oxygen-acetylene was advanced. Like all new and very radical ideas it did not meet with instant approval. Most thinking along the lines of a substitute for chipping followed the lines of chipping machines.

Like all beginnings, scarfing equipment was rather crude. No one knew how the equipment should be used. Cylinder gases and oxygen had to be used.

The work had a very sloppy appearance and the cutting tips left much to be desired.

The first major complaint was scarfing wash. This was caused by poor torch handling and lack of knowledge of gas pressures. Inspectors claimed this wash

George Mersot is General Foreman of Billet Conditioning, Indiana Harbor Works of the Inland Steel Co., East Chicago, Ind.

This paper was presented before the Annual Meeting of the International Acetylene Association, Pittsburgh, Pa., April 25-26, 1949.

Fig. 1 Scarfer at work on 2¹/₂-in. square billets. Note upright position of scarfer and ease of operation

covered adjacent surface defects and would cause scabby surfaces on rerolled bars. This defect was partially overcome by using a scraper. These were made from a thin piece of spring steel about 4 in. wide welded to a handle 36 in. long. By sharpening the edge of the flat piece it could be used as a chisel for getting in under the slag and removing the fins or burrs.

The next obstacle to be overcome was the elimination of gouge created by starting the scarfing cut. A starting device did not exist. To get a preheat necessary before cutting, the scarfer had to angle his tip down on the surface. When the spot was heated sufficiently the cut was started by applying high-pressure oxygen and a gouge was dug that at times was deeper than the defect to be removed. You can readily see that the most alert scarfer had great trouble keeping this defect minimized.

After much practice making starts and many discussions with operators and servicemen we were ready to admit defeat and accept what we had as the best we could do.

Most of us working with scarfing as a means of steel conditioning like to feel we have contributed something to the art. Our claim is the idea of a starting rod. The device to be used for the rod was perfected by others.

An operator asked permission to use a piece of bailing wire in front of his tip. We had tried everything else so we decided to try this. A piece of wire about 8 ft. long was given to the man that helped the scarfer. At the direction of the operator the wire was held at the end of the tip. When the wire started to melt the operator applied the cutting oxygen and a perfect start was accomplished. We continued this practice until a device was made that could be operated from the torch. By using a starting rod, preheat time was reduced, the starting gouge was eliminated, and the greatest objection to scarfing was overcome. The quick development of the starting rod feed mechanism showed to us the value of an equipment manufacturing service department working closely with the users of equipment.

The users of scarfing as a means of conditioning semi-finished products have problems peculiar to themselves. The type of product to be conditioned, the space available, the amount of crane capacity, and the tonnage required to be conditioned all determine the skid or table arrangement necessary to best do the job. The scarfing dock should be placed where most space is available and the least handling of material required.

Where billets that are 2 x 2 to 5 x 5 in. square and lengths of 10 to 20 ft. are conditioned, a table can be used with good results. This table should be 30 in. high, 30-ft. in length and 10 ft. in width. The gases for scarfing are piped to the center of the table and the hoses that are attached to the torch are suspended from a swinging overhead arm.

Bumper posts should be put in the middle of the table splitting it in half. This allows for billets to be put on both sides and worked alternately, thus giving continued operation. The selection of the proper torch is very necessary. The torch should be short, light in weight and capable of cutting fast and with low-oxygen pressure. The height of the table allows the operator to be in close range of his work, reduces fatigue and makes shallow cutting easy.

Handling billets and slabs requires a rather different layout. Billets 6 x 6 in. square and larger, slabs 20 in. to 50 in. wide and 8 ft. to 16 ft. in length are best worked on the floor. Steel blooms 8 to 10 in. square make ideal skids on which to place material for scarfing. Where a high skid is desirable, soft rails with 8-inch. I-beams welded to the rail base gives satisfactory results. The height of the skid can be best determined by the amount of crane time available for clearing the floor of scarfing slag. The higher the skid the less time required to do this chore.

Most scarfing today is being performed on slabs for rerolling into strip products. In most conditioning docks, the slabs are spread out flat on the skids. In a few, the slabs are tilted by placing the material on light section I-beams or short steel blocks about 6 in. in height. The slabs are tilted to allow scarfing slag to run off the slab thus reducing the amount of fin. The scarfers like the idea of the tilt. They say heat fatigue is

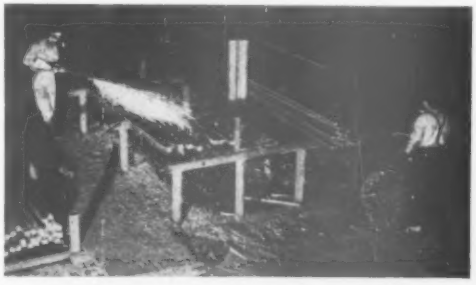


Fig. 2 Table separated into two parts. This makes possible continuous operation

reduced. Of course more time is needed for tilting than is used in spreading material flat.

Slabs are best handled by magnets. The material can be spread, turned and piled quicker with the magnet than with any other means. The overhead crane is used for this operation in most conditioning docks.

The overhead crane is of necessity high. It, therefore, has a lengthy drop of cable to reach the job. This causes the magnet to sway when put to work turning slabs; it makes spotting difficult. Extra moves have to be made at times because of this condition. The overhead-crane operator rides in a cab that is on the average 30 ft. off the ground. This distance adds to his difficulties in spotting material.

The most efficient means of handling slabs on a scarfing dock is by using a low-Gantry crane. This type of crane is low enough to operate under the overhead crane without causing confusion. There are no long cables and the operators cab is very close to the ground. A ram is used instead of cables for the lifting operation. To this the magnet is attached. This gives a rigid setup that eliminates all swaying. Spotting becomes simple and extra moves unnecessary. Because of this, material can be spread, turned, and piled more quickly, and naturally, a greater tonnage can be handled.

The proper selection of the tool for the job at hand is very important. Slabs that require complete surface removal have available the widest range of torches and tip sizes. The torch we employ is 36 in. long, and it can stand a lot of hard use. A slab 40 in. wide can be skinned with 37 cuts using this tip. If the slab is 90 in. long, complete surface removal can be accomplished in 36 min. It is therefore possible for an operator to skin about 13 slabs per day. This torch is well liked by the operators. It develops less heat and therefore reduces heat fatigue.

Fig. 4 Ideal slab scarfing layout. Note lack of interference from torch flame

Different lengths are available in the newer torches, but we employ those 44 in. long. They are light in weight. The rod feed and high-pressure oxygen are on the same lever.

The operator can get his starting-rod feed and cutting oxygen with one movement of his hand. With the tip that gives the best results, a wide cut is obtained with this torch; a 40-in. slab, 90 in. long, can be skinned in 25 min. About 25 cuts are required. Best results are obtained by using a $^1/_2$-in. hose for the oxygen lead to the torch. This gives the needed supply of oxygen to maintain the full width of cut possible by this tip. This blowpipe is liked by tall operators but not by short ones. This is due to length. They all object to the extra weight caused by using $^1/_2$-in. hose.

With the newest blowpipe developed, a slab of the above-mentioned size can be skinned with 17 to 20 cuts depending upon the operator. The time required is 15 min., and it is possible to complete 32 slabs in one day. Were this size of slab chipped, only one at most would be finished. This latest torch is also 44 in. long, and needs a $^1/_2$-in. hose for the oxygen.

Like all things different, this new

Fig. 3 Scraper for removing scarfing fins or burrs

Fig. 5 Overhead and Gantry cranes in operation at the same time

torch meets with some disfavor. The main objection is the excessive heat caused by the large tip. On complete skinning, metallic loss is the main objection of the steelmakers. Depending on tip size, metallic losses range from 2½ to 5%. This loss is the price paid for increased production.

The scarfing of billets and blooms is best done on skids similar to the ones used for slabs. The skids should be movable to allow for quick change to accommodate varying lengths.

The overhead crane for service is best suited for this material. Billets are usually bundled. Here, chains are best used on small sizes, and cable sway is not so important.

It is not generally necessary to completely remove the surface of billets. The work is generally "spot" work; this consists of removal of scattered seams and flaws of various lengths and depths. Only the most experienced operators should work on blooms or billets. Proper flaring of deep cuts and uniformity of depth in cutting are very important.

Billets and blooms are usually ordered by weight per piece. Little extra weight is allowed for conditioning. It is therefore necessary to keep metal removal to a minimum. (Once again the need for only the experienced operators.) The number and kind of operations material goes through, and the end use, determines the kind of conditioning required. The average output scarfed is about 25 tons per man-day. The same material chipped is about 8 tons per man-day.

With the development of new equipment such as preheat and stress-relieving furnaces, materials can now be scarfed that were considered impossible a short time ago. The development of a cobalt-base alloy ring on the end of cutting tips has cut tip costs by eliminating abrasive wear that ruined the old ones. The development of piped oxygen and acetylene has reduced gas supply delays. The old or original method of using cylinder acetylene and oxygen hooked up to a manifold caused costly delays because empty tanks had to be handled and hooked up. We now have a continuous flow of piped oxygen and acetylene on the job at all times, and can maintain uniform pressures.

The installation of oxygen converters and acetylene generators for cutting fuel has cut costs in half and has made possible the use of machinery for scarfing at the blooming mills. It is now possible to remove the surface completely on various sizes of square billets at the delivery side of the mill. This has brought about lower costs at the final conditioning docks.

Scarfing has contributed to greater efficiency, greater output and lower costs at the conditioning-docks. There is, however, much still to be done. Machinery should be developed for scarfing wide surfaces both hot and cold. It should be possible to change the machine from small blooms to wide slabs with a minimum of delay. The need for machinery is great and is a challenge to the manufacturers of equipment. Can it be met?

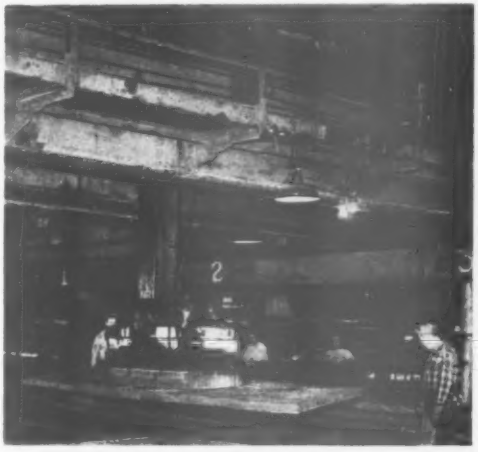


Fig. 6 Gantry crane in operation. Magnet attached to crane ram adds to the efficient handling of slabs for piling and spreading

WELDING METALLURGY—Iron and Steel

The Society has revised the Welding Metallurgy book originally published in 1940. The book has been brought up to date and a wealth of new material added. This book is being reproduced serially in* The Welding Journal. *Copies in attractive imitation leather covers are available at $2.50

by O. H. Henry, G. E. Claussen and G. E. Linnert

Chapter 3
WELDING METHODS AND PROCESSES

In order to join two or more pieces of metal together by one of the welding processes, the most essential requirement is heat. Pressure may also be employed, but this may or may not be essential. We have yet to learn how to weld the metals which we commonly use for construction into firm union without the application of heat. A few combinations of noble metals, like gold or silver, have been *welded* by pressure alone, so perhaps the day will arrive when aluminum, copper, or steel will be easily joined by a heatless welding process.

There are 37 welding processes in use today, as shown on the *Master Chart of Welding Processes* on the next page. Many of these processes are used with variations in equipment and technique. Some of the processes have limited application, while others find more general use.

Before discussing these processes in further detail it may be helpful to point out that all of them fall into the following basic types:

1. Those processes where the parts to be joined are melted together, with or without filler metal. Pressure is not a requisite. Examples are shielded metal-arc welding and oxy-acetylene welding.

2. Those processes where the molten metal is added to heated but not molten base metal. The distribution of the filler metal is accomplished by capillary attraction, and pressure is not a requisite. Examples are brazing and soldering.

3. Those processes where the joint is made by a combination of heat and pressure, without any appreciable melting of the parts involved. Examples are forge welding and pressure gas welding.

THE GENERATION OF HEAT

Some remarks, which may help to simplify the array of welding processes even further, can be made on the means available for generating heat for welding.

Basically, only three means—electrical, chemical, and mechanical—are employed in our presently used welding processes. Electrical and chemical means have been most successful, and consequently their use is widespread. Mechanically produced heat, as might be developed through friction or impact, has seen only very limited use.

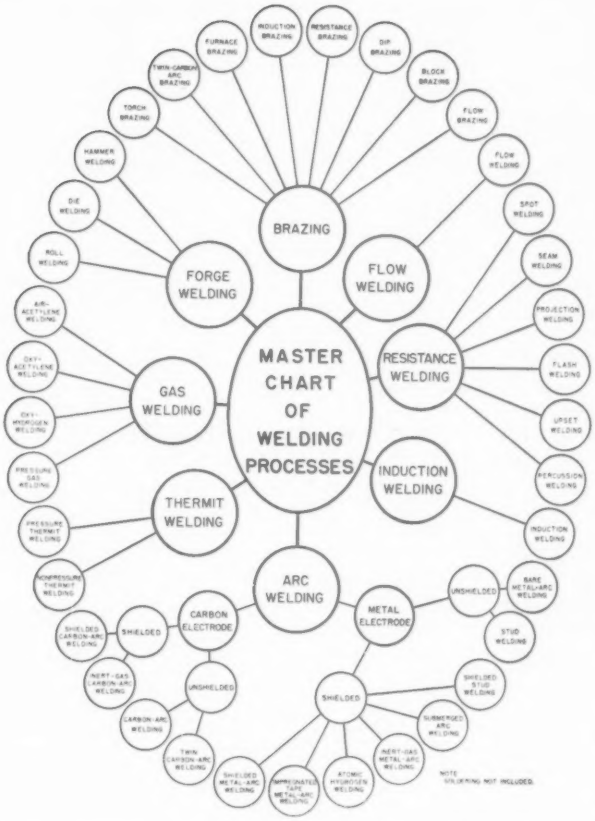
Electrical Methods

Three electrical methods are used for heat in welding; the electric arc, electrical resistance, or induced electric current. The electric-arc may be considered as an electric current passing across a gap of high resistance by means of ions, or in other words, a sustained electrical discharge over a gaseous path, between two poles or contacts. The gaseous path is the arc, and it is made up of various gases and vapors, some of which are ionized. Ionized particles are atoms that have lost an electron and in this condition are good conductors of electricity. They have short lives and exist only in the arc, to which, by their extreme rapid motion, they impart high temperature. High temperature is nothing more than the rapid motion of atoms, molecules, or ions. The ions may be secured from the air in the gap, metal vapors, or entirely from foreign materials introduced into the arc as *arc stabilizing agents*. The heat developed by an arc can be calculated by use of the following simple formula:

$$\underset{\text{Heat}}{W(\text{joules})} = \underset{\text{Voltage}}{E(\text{volts})} \times \underset{\text{Current}}{I(\text{amperes})} \times \underset{\text{Time}}{t(\text{seconds})}$$

A joule represents energy in the form of heat which is transformed by the arc. As an example, an electrode being operated at a current of 300 amperes with a closed circuit voltage of 20 liberates 6000 joules per second. If the electrode traveled along a weld joint at a speed of 6 inches per minute (10 seconds per inch), the arc would generate 60,000 joules per inch to fuse the weld.

A piece of metal may also be heated by its resistance to passage of an electric current through it, or by an induced electric current. When an electric current flows between two contacting pieces of metal, heat is developed at two particular locations; in the body of each piece, and at the contacting surfaces. The heat developed in the body is determined by the inherent electrical resistivity of the material, while the heat developed at the contacting surfaces is determined by contact resistance. The contact resistance between two pieces of metal depends upon a number of factors, among them being the inherent or characteristic resistivity of the materials, the pressure holding the pieces together, whether the surfaces are coated with oxides or compounds of high electrical resistivity, and so forth. The quantity of heat produced is determined by the amount of current passed through the pieces, the over-all resistance which the assembly of pieces offer to the passage of current, and the length of time the current flows. We also find that the amount of heat is



directly proportional to the square of the current as illustrated by the following formula:

$$W(\text{joules}) = I^2(\text{amperes}) \times R(\text{ohms}) \times t(\text{seconds})$$
$$\text{Heat} \quad \text{Current} \quad \text{Resistance} \quad \text{Time}$$

It is possible to employ other materials besides the metals to be joined to generate heat by electrical resistance. Certain molten slags are conductors of electricity and their resistivity is high enough so that heat can be generated to not only keep the slag molten, but also melt an adjacent body of metal.

Chemical Methods

Heat for welding can be evolved from chemical reactions between gases or solids. In gas welding we call the chemical reaction between fuel gas and oxygen *combustion* or *oxidation*. Another type of reaction which can take place in a gas and liberate heat is the combination of single atoms of a gas to form a diatomic gas. This method is employed in the atomic-hydrogen welding process to transfer heat from an electric arc to the surface of the metal to be heated. This process is described in detail later in this chapter.

While heat is given off by a number of reacting solids, the reaction of practical use in welding is that which occurs between a metal oxide and another metal which has a greater affinity for oxygen than the metal already in the oxide compound. Under proper conditions, as will be described later under the *Thermit Process*, the metal can be made to replace the metal in the compound through a vigorous replacement reaction which evolves a considerable amount of heat.

WELDING PROCESSES

In the paragraphs to follow, a short description is given of the major welding processes. The foremost aim of these descriptions is to show how each process operates and the conditions of temperature, atmosphere, and so forth, which they impose upon the metal being welded. Later we shall see how these particular features play an important part in determining the metallurgical properties of the weld joint.

Arc Welding

The electric arc is highly desirable as a source of welding heat for a number of reasons. Its extremely high temperature permits it to supply a large amount of heat to a small area. The temperature of the welding arc is approximately 11,000° F as compared to 6000° F for an oxy-acetylene gas flame. Also the arc and surrounding atmosphere are not laden with products of combustion as found in the case of the gas torch. In fact, artificial atmospheres of desirable gases can be created in and around the arc with little difficulty.

The current for a welding arc is usually supplied through a special machine or device which converts the electrical current in our regular power lines from high voltage-low amperage current to low voltage-high amperage current, which is safer to use and produces heat more efficiently. According to common electrical theory, the current flows from the anode or positive pole, to the cathode or negative pole. Another school of thought, however, pictures a flow of electrons (particles of negative electricity or negative charges) from the cathode to the anode. Regardless of our conception of an electrical current, the current flow may be continuous in one direction in which case it is called *direct current*, or it may reverse its direction of flow with regular frequency in which case it is called *alternating current*. Generally, direct current (d-c) for welding is supplied by motor-generator machines, while alternating current (a-c) is supplied by transformer type welding machines. For alternating current, 60 cycles per second is the most commonly used frequency, but higher frequencies are employed in some processes in order to help maintain a stable arc.

There are two simple ways of using an arc to provide welding heat. It can be established between two poles or electrodes and then held close to the metal surface to be heated, or the arc can be placed in intimate contact with the surface by making the base metal a part of the electrical circuit. In the latter case, an electrode is used as one pole and the base metal acts as the opposite pole.

Direct current may be used under two conditions of polarity; *straight polarity* where the electrode is the negative pole and the base metal is the positive pole, or *reverse*

polarity where electrode and base metal are now just the reverse. An arc operating on alternating current is broken and remade each time the current reverses. Consequently, when operating on 60 cycle alternating current, straight polarity conditions prevail for $^1/_{120}$ of a second and reverse polarity for the second $^1/_{120}$ of a second: that is to say, the polarity changes with each half-cycle of current.

The polarity of direct current in welding is important in determining the depth of penetration into the base metal and the rate at which the electrode is consumed. More heat is liberated at the positive pole of an arc than at the negative pole when a bare electrode is used. (This may or may not be true with coated electrodes.) Consequently, on straight polarity the penetration into the base metal is deep and the melting of the electrode is minimized. Conversely, on reverse polarity the penetration is shallow and the electrode is heated more intensely. The more rapid heating of the positive pole or *anode* has been attributed to the bombardment of this area by the electrons flowing at extremely high velocities from their point of generation at the negative pole or *cathode*.

By having the arc play directly on the base metal, as we find in the case of a single electrode, extremely rapid heating is secured. The electrodes can be made of a more or less permanent material so that the electrode does not enter into the welding operation in any way other than acting as a pole to support the arc. Carbon or tungsten are favorite electrode materials because they have high melting points, and, perhaps even more important, very high boiling points. As electrodes, they are consumed slowly by a combination of melting, vaporization, and oxidation.

Arc welding in the simple form just described is used to only a limited extent today as compared with the other refined or modified welding processes to be covered. The principal reason appears to be that some form of shielding is required by most metals to protect them from the damaging effects of oxygen and nitrogen in the air.

Bare Metal-Arc Welding

This process represents one of the early modifications of the basic arc-welding process just described. Instead of employing a permanent electrode material like carbon or tungsten, the metal-arc processes use a consumable metal electrode, which may be iron, steel, nickel, aluminum, etc. As the electrode is melted by the heat of the arc, the metal is deposited in a puddle or molten crater on the base metal. In this way the metal electrode serves as both electrical pole and filler metal. As the arc burns between the electrode and the base metal, the heat liberated also melts some of the base metal, which is generally stirred into the deposit from the electrode to form a homogeneous mixture. The amount of base metal that is melted depends to some extent upon the melting point of the electrode. For example, a bronze electrode (melting at approximately 1800° F) deposited on a plate of mild steel will melt less of this base metal than will a mild steel electrode (melting at approximately 2750° F). However, other factors, such as polarity of current, travel speed, and voltage, will influence the amount of base metal melted as we shall learn in later chapters.

Shielded Metal-Arc Welding

Shielded metal-arc welding uses covered or coated electrodes which are steel rods or wire with an outside sheath of fluxing and slag-forming ingredients, Fig. 8.

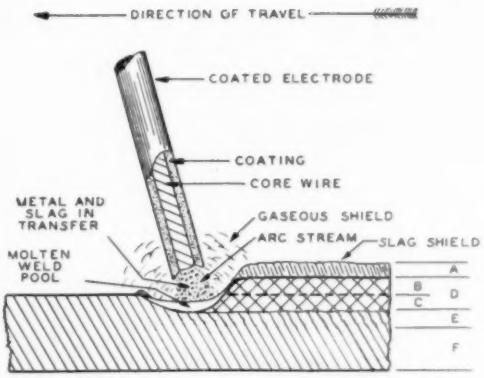


Fig. 8—Diagrammatic Sketch of Flux-Coated Metal-Arc Electrode During Deposition

A—Slag layer
B—Weld reinforcement
C—Penetration
D—Weld deposit
E—Base metal heat-affected zone
F—Unaffected base metal

These coatings are carefully formulated, and play a major part in the operation of the electrode. They stabilize the arc, shield the metal during transfer through the arc, control the viscosity of the weld metal, protect the deposited weld bead as it solidifies and cools to room temperature, and so forth. The composition of electrode coatings and their function in shielded metal-arc welding are discussed in detail in Chapter 8.

When automatic machines are employed for shielded metal-arc welding, we are immediately confronted with the problem of passing welding current into the electrode wire. Obviously, if the wire is covered with a solid coating of fluxing ingredients it is effectively insulated against the current. If the electrode is in a straight length and not too long, we can make contact at the upper end just as we do on a manual electrode. A very long electrode, of course, will become heated because of the greater resistance it offers to the passage of the current. Generally we prefer to carry out our automatic welding with wire in coil form, and therefore must employ a device that will permit passing the current into the wire reasonably near the arc end. It is possible to use heavily covered electrode wire in coils by feeding it through an automatic head that cuts a narrow slot in the covering to permit a current-carrying shoe to contact the wire. A more recent development is a covered electrode wire in coil form that has a smaller diameter wire spirally embedded in the flux covering. This small wire is wrapped tightly against the surface of the larger electrode core wire, and is exposed at the surface of the covering also. This smaller wire passes the current from the contacting shoe in the automatic welding head to the larger, central core wire. Many innovations are used to overcome the current passing problem.

Inert-Gas Metal-Arc Welding

Inert-gas metal-arc welding may be carried out with a permanent metal electrode or a consumable metal electrode which contributes filler metal to the weld deposit. To protect the molten metal in the weld pool from the adverse effects of oxygen and nitrogen in the air, a soft stream of an inert gas flows from an inverted cup or shield around the electrode and forms a gaseous protective cover over the weld pool as shown in Figure 9. The process when first introduced on a commercial scale, made use of a permanent tungsten electrode, but equip-

ment has since been introduced for performing inert-gas metal-arc welding with a bare consumable electrode. This form of the process eliminates the inconvenience of adding a filler rod when additional metal is needed. This is an important factor in securing greater welding speed and improved deposits, as we have already learned from the development of unshielded metal-arc welding.

Both carbon and tungsten has been successfully used as permanent electrode materials in the process. When

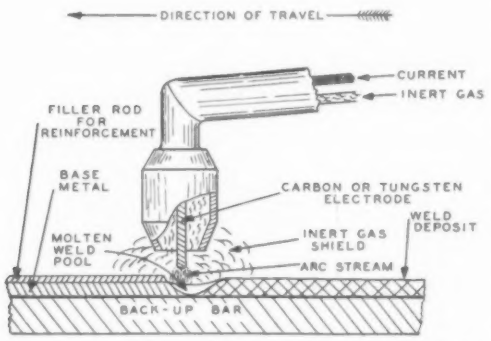


Fig. 9—Diagrammatic Sketch of Inert-Gas Shielded-Arc Welding Using Argon or Helium as an Inert Gas

the electrode is carbon, the process is referred to as *inert-gas carbon-arc welding;* and when tungsten, as *inert-gas metal-arc welding.* The inert gases commonly employed are argon and helium. These two gases do not affect the electrical characteristics of the arc in identical fashion, and therefore are not entirely interchangeable. Whether argon or helium is chosen will depend upon the composition of the base metal being welded, its thickness, kind of welding equipment employed, and other factors. When 60-cycle alternating current is used, some transformer type machines include a spark gap oscillator to provide a small high-frequency current which is superimposed upon the regular 60-cycle welding current to provide easier starting of the arc.

When direct current is employed in this welding process, and a permanent electrode is to be used, the electrode is usually made the negative pole. That is to say, the circuit or electrode-work arrangement is one of straight polarity. The use of reverse polarity results in undesirably high electrode consumption because of the greater amount of heat liberated at the positive pole; which in this case would be the electrode. The polarity also affects the tendency of some metals to form an oxide film on the molten weld pool. Aluminum and its alloys form an objectionable oxide film when welded with straight polarity, but under reverse polarity conditions the film is almost non-existent. Because of the excessive electrode consumption experienced on reverse polarity, the use of alternating current is favored for the welding of aluminum and its alloys. Here, the rapid reversals of polarity minimize the oxide film-forming tendency and the consumption of the electrode is more readily tolerated.

This process was first employed in joining aluminum and magnesium because of the difficulty in adapting the shielded metal-arc process to them. Its use has now been extended to other materials which require efficient protection from the atmosphere during welding, like the chromium-containing stainless steels. The process has been particularly useful in the welding of thin sheet where square-butt or similar joints can be fused or melted down at high speeds using a permanent electrode. Where some filler metal is needed, it can be supplied by merely laying a small diameter rod or wire on top of the joint and fusing it into the seam.

Atomic-Hydrogen Welding

In the atomic-hydrogen process the heat of an arc is used indirectly as a source of welding heat. An arc is established between two tungsten electrodes using alternating current. At the same time, streams of hydrogen gas are passed along the electrodes, through the arc, and toward the base metal to be melted. The hydrogen gas prior to entering the welding arc is in the molecular form which consists of hydrogen atoms held in pairs (H_2). The arc heats the hydrogen to a high temperature, perhaps 9000° F. Leaving the arc, the hydrogen strikes the metal to be welded, raising its temperature and melting it, using the additional heat of combination. At high temperatures molecules of hydrogen fall apart. Each molecule of hydrogen becomes two separate hydrogen atoms. To disconnect the hydrogen atoms in a molecule requires heat, which is provided by the arc. When the hydrogen atoms cool below the temperature at which they fell apart, the atoms connect together in pairs again with the evolution of heat. The relatively cool surface of the metal to be welded provides the low temperature necessary for the atoms to join to form molecules. The heat liberated by the junction raises the temperature of the metal. The arc in atomic-hydrogen welding heats the metal not only by imparting its thermal energy, but also by the heat of combination of hydrogen atoms. The hydrogen is adjusted to prevent admixture with the surrounding air. On the outer surface of the hydrogen stream, combination of hydrogen with oxygen occurs, which is essential to the process only in so far as it prevents oxygen from diffusing far into the hydrogen stream. The metal being welded is surrounded by hot hydrogen. Small amounts of iron oxide on the surface of the steel are reduced to iron by the hydrogen. No flux ordinarily is required, for there is no oxygen and consequently no oxide. The oxides of some metals, such as aluminum and chromium, are not rapidly reduced to metal by hydrogen even at high temperatures. For these metals, that is, aluminum, magnesium and stainless steel, flux is used particularly on the underside of the weld to which the stream of hydrogen cannot penetrate.

Submerged-Arc Welding

This welding process is still another form of metal-arc welding in which a new device is used for shielding the arc flame and molten metal from the oxygen and nitrogen in the atmosphere.

The welding heat for the submerged-arc process is generated by the passage of an electrical current (a-c or d-c) between the end of a bare electrode wire and the base metal to be welded. Special welding machines, either automatic or semi-automatic, are used to support and feed the electrode wire. Instead of permitting an air gap to exist between the electrode and the work, the end of the electrode is submerged in a mound of finely granulated flux or slag which is heaped along the joint to be welded. When the current flows through this circuit, a portion of the granulated flux immediately surrounding the electrode end becomes molten. This molten blanket of material is very effective in shielding the arc and the molten weld metal from the atmosphere (Fig. 10).

The fluxes or slags used in this process are generally silicates, possibly calcium aluminum silicate, which are fused and finely pulverized before use. Powdered metals or alloys may also be added to the granular flux so that

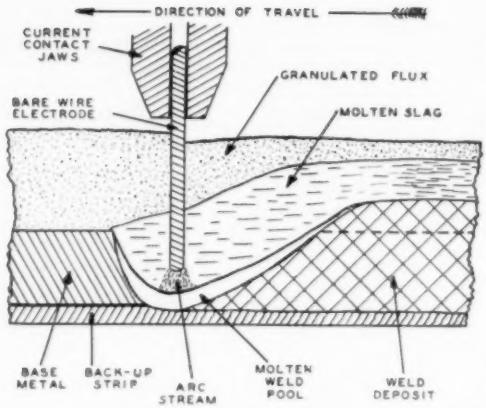


Fig. 10—Diagrammatic Sketch of Submerged-Arc Welding Operation on Heavy Plate Using a Permanent Back-Up Strip

they will enter the weld deposit during the melting operation. The process is unique because extremely high welding currents may be employed without experiencing a rather violent arc. The current is often five times as high as used in shielded metal-arc welding, but the submerged-arc behaves nicely beneath the blanket of molten flux. The high currents, of course, lead to deep penetration of the base metal and fast deposition of the electrode wire.

Spot, Seam, and Projection-Welding

All resistance welding processes have the common feature of requiring the use of pressure. The extent of fusion taking place in the pieces that are joined depends upon the conditions of temperature, time, and pressure imposed upon the metal. Heat is generated by the passage of a current (usually a-c) through the one or more pieces of base metal. While some heat develops in the body of each piece because of its electrical resistivity, a large portion of the welding heat develops at the surface because of contact resistance.

In making a spot weld, the pieces to be joined are clamped between electrodes made of a copper alloy. Pressure may be applied through the electrodes by a number of systems; either springs, levers, cams, hydraulically, or pneumatically. The current that is passed through the pieces usually is of very high amperage, but passes for only a very short time. In welding two thicknesses of 0.125-inch clean low-carbon steel a current of 20,000 amperes would be allowed to flow for about one-third of a second. Imagine the rapid heating that takes place in the metal. We shall explain later how rapid heating also leads to rapid cooling.

A fairly recent innovation in resistance welding technique is to provide equipment on the resistance welding machine so that the pieces held between the electrodes can be subjected to a series of operations in rapid-fire order. It is possible with a machine of this kind to (1) apply clamping pressure, (2) pass low current for preheating, (3) pass high current for welding, (4) permit a measured length of time to elapse so that the weld may cool, (5) pass either high or low current for some particular heat treatment, and (6) perhaps apply increased forging pressure for grain refinement. A welding program something like this might be used for joining a hardenable alloy steel, which would be prone to crack if welded with one surge of current and cooled without any precautions.

Along with spot welding, we could also list seam welding and projection welding. These processes are simple modifications of the spot-welding process. For seam welding, the electrodes are replaced with wheels of copper alloy. As the base metal pieces are passed between the two wheels, impulses of current form a series of overlapping spot welds. Projection welds are made by providing an embossment or projection on one or both of the contacting base metal surfaces to localize the pressure and current flow at a particular point. This simply reduces the amount of current and pressure required to produce a spot weld between two pieces of metal.

Upset Welding

In this process the pieces to be welded are gripped in copper dies or jaws and held in their required position with their mating surfaces in contact. Current and pressure are applied simultaneously. Sufficient heat is generated by contact resistance at the junction between the pieces to bring about some fusion of the mating surfaces. The pressure applied during the heating period upsets the abutting sections and tends to force any molten metal which may have formed out of the junction. Unless some special precaution is employed to protect the joint from the air, such as enveloping it in an inert gas or burning hydrogen, a considerable amount of scale or oxide will have formed on the mating surfaces during the heating period. An appreciable upset is required to insure a clean, sound weld.

Flash Welding

While this process is very similar to the upset welding process, it possesses several distinct advantages which are gained through differences in operating procedure. A flash weld is made by holding the pieces to be welded in copper jaws, but in very light contact. A current is passed across the juncture. Heat is generated mainly by the contact resistance of minute short circuits which occur in extremely fast succession between the faying surfaces. Rapid superficial melting takes place at these points and incandescent particles of metal are blown out of the joint. This flashing action is sometimes erroneously referred to as an arc. The pieces are slowly propelled together to compensate for the metal loss in flashing and thus continue to bring new points in contact. When the entire abutting surfaces are molten, the current is stopped and the two pieces are immediately forced together under considerable pressure. A thin film or *flash* of metal is squeezed out of the joint. In this way, any oxidized metal is easily eliminated from the joint and deformation of the section at the joint is remarkably small.

Percussion Welding

Percussion (or percussive) welding has been used only to a limited extent. The equipment is difficult to build and operate, and the process is confined to butt-type joints of limited size. Nevertheless, the process is unique and of considerable interest because butt welds can be made with incredible speed, in almost any combination of dissimilar materials, and without the expulsion of a fin or flash around the joint.

The pieces to be joined are held a short distance apart in clamping dies which carry current and apply pressure. The ends to be welded are carefully prepared for accurate mating. An extremely heavy electric current is delivered (electrical energy delivered by discharging condensers) to the pieces as a very short impulse, perhaps for only one-thousandth of a second, and flows across the gap between the pieces as an arc. The heat of this high-energy arc produces superficial melting over the entire end surfaces of the bars. An instant after the arc has struck, the

pieces are brought together with an impact blow to complete the weld. The weld fusion zone and base metal heat-affected zone together comprise only a narrow band a few thousandths of an inch wide.

Gas Welding

The parts to be joined by gas welding are fused or melted together, without pressure, and with the addition of filler metal from a welding rod as required. The source of heat is a gas flame which issues from a welding torch. Flames can be produced of sufficient intensity to melt any metal or alloy. The most common fuel gas used in gas welding is acetylene. Hydrogen, butane, propane and other similar gases are also used. These fuel gases are burned in purified oxygen, and less frequently in air, to secure a flame hot enough for welding.

Besides producing a flame temperature of approximately 6000° F, the highest of any known gas flame, the character of the oxy-acetylene flame can be varied by controlling the relative proportions of acetylene and oxygen issued at the torch tip, Fig. 11. When equal volumes of acetylene and oxygen are burned the flame is called a *neutral flame* and consists of two distinct parts; a

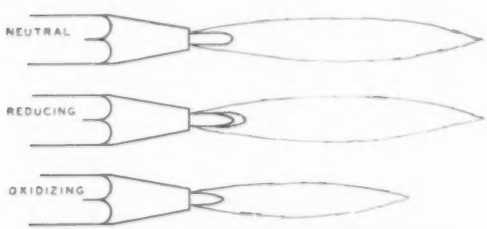


Fig. 11—Three Types of Oxy-Acetylene Flames Used for Welding

small bright inner cone where the two gases combine to form carbon monoxide and hydrogen, and a larger outer flame where an additional $1^1/_2$ volumes of oxygen picked up from the air are used to burn the CO and H_2 to carbon dioxide (CO_2) and water vapor (H_2O). A *carburizing* or *reducing* flame can be produced by increasing the acetylene slightly over the one-to-one mixture. This adds a third zone to the flame; an irregular feather or fringe surrounding the inner cone caused by free carbon combining with oxygen. When oxygen in excess of the one-to-one mixture is used, the flame becomes oxidizing. In this case, only an inner cone and outer flame are again present, but the shape and color of the inner cone can easily be distinguished from the cone of a neutral flame.

Two important points in any gas-welding technique are: (1) the adjustment of the proper type of flame, that is, neutral, reducing, or oxidizing, and (2) the selection of the proper type of flux, if any is to be used. Both of these points are determined by the properties of the metal to be welded. When welding brass, for example, an oxidizing flame is used. This maintains a film of oxide on the surface of the molten metal and prevents the evaporation of zinc from the melt. Zinc melts at 787° F and boils at 1665° F, and so there is a strong tendency for the zinc in the brass to boil out. On contact with the air the evaporated zinc burns to a white powdery oxide which is useless in preventing further loss of zinc by evaporation from the melt.

Most gas welding, however, is performed with a neutral or reducing flame. This is particularly true in welding ferrous alloys where we are generally confronted with the problem of avoiding excessive loss of carbon or other valuable alloying elements by oxidation. Some protection from oxidation is given to the metal by burning gases which are passed over the surface. The *reducing* flame is, of course, the more protective flame. Nevertheless, some oxidation will occur owing to the infiltration of the air into the flame as it is played back and forth over the joint. If the molten pool contains elements which oxidize to form viscous oxide slags, like chromium or aluminum, it is then necessary to employ a flux in the operation. The action of fluxes in gas welding is discussed in detail in Chapter 8 of this book.

Pressure Gas Welding

It has been mentioned several times in the foregoing descriptions of welding processes that a joint can be welded by the proper application of heat and pressure without any of the metal ever reaching the molten stage. This kind of welding has been referred to as "solid phase" welding. The commercial adaptation of this method, called pressure gas welding, is carried out by heating a joint to a temperature somewhere below the melting point of any of the component members while the joint is held in compression. When the joint is held for a sufficient length of time at this temperature under pressure, bonding or welding will occur. Any light oxide films on the faying surfaces gradually break up and slowly diffuse into the body of the members. Grains grow across the juncture. Finally, little or no evidence can be found that a joint existed.

The heating of the joint can be done with an electric induction coil or with a gas torch. The advantages of pressure gas welding are that the relatively slow heat input of the oxy-acetylene flame is not likely to lead to thermal cracking, the absence of weld metal eliminates problems with blowholes, shrinkage cracks, and other defects associated with cast material, and the slow cooling rate after the flames have been removed will not cause intensive hardening or cracking in hardenable steels.

Most of the disadvantages of this process are purely mechanical. A press is needed for applying substantial pressure. An arrangement of heating torches that will encompass the entire joint and heat it uniformly must be provided. Temperature control is also required. Care must be taken during the heating period to maintain intimate contact between the surfaces to be bonded for if any separation takes place the atmosphere will enter and cause excessive scaling which will hamper the bonding of the surfaces. The combination of temperature and pressure will generally result in considerable upsetting of the section at the joint, which is a desirable condition because any unwelded portions around the outer edges will be removed when the upset metal is machined off. The shape of the sections to be joined is important. So far, the process has been used with good success in making butt-type joints in round, square, and rectangular bars, heavy walled tubing, and railroad rails.

Most materials are readily joined by pressure welding. A few require special attention because of their inherent characteristics. Alloy steels containing substantial amounts of chromium bear watching because the scale which forms on their heated surfaces is more difficult to break up and diffuse. A stainless steel containing 18% Cr and 8% Ni which melts at approximately 2780° F would be pressure welded by heating to approximately 2200° F and holding at this temperature for about five minutes. The ferritic variety of stainless steels requires careful heating practice to avoid growing abnormally large grains in the material. When some grades of medium-carbon low-alloy steel are pressure welded, the microstructure upon being etched by a special reagent displays evidence which suggests that oxygen in high concentrations is dissolved in the metal over a short distance on either side of the junction. This condition impairs the mechanical properties of the joint. The use of inert

atmospheres or controlled atmospheres to prevent scaling and eliminate gas absorption has not yet reached the practical stage in pressure welding.

Forge Welding

Forge welding consists of heating the surfaces to be joined, placing these surfaces in contact, and hammering them together to form a weld. The scarves, as the surfaces to be welded are called, generally are heated in a fire that causes oxidation. It is true that a carburizing forge fire will create a liquid layer of high-carbon, low-oxygen metal on the surface which may facilitate welding. However, the carburization usually leads to brittleness and is difficult to control. The oxidizing fire creates a liquid film of iron oxide on the surface. Sand is sometimes used as a flux for it dilutes the iron oxide by forming silicates. As a result less oxygen diffuses into the steel than without a flux. When the solid surfaces are hammered together, the fluid slag is squeezed from the weld joint more or less completely. The adaptability of wrought iron to forge welding lies in the silicate slag (2 percent by weight) of low-melting temperature contained in the metal. The slag acts as a flux to protect the hot iron surfaces from the oxygen in the air.

Thermit Welding

A *thermit* mixture is a means of chemically generating heat rather than being a welding process and consists of powdered aluminum and iron oxide in proportions of about one part aluminum to three parts iron oxide by weight, respectively. When this material is heated locally with a special ignition powder, a vigorous replacement reaction takes place which proceeds rapidly through the mass. The aluminum, having a much greater affinity for oxygen than iron, reduces the iron oxide and liberates a considerable amount of heat. The entire mass becomes molten; the reduced iron metal settles to the bottom and the aluminum oxide slag floats to the top.

In carrying out a thermit welding operation, the thermit mixture is placed in a refractory crucible above the pieces to be welded. In practice, additional metals and compounds are often placed in the thermit mixture to alloy the iron and improve its properties. Four different mixtures are commonly used: (1) plain thermit, (2) steel thermit, (3) cast-iron thermit, and (4) wear-resistant thermit. The temperature created by the thermit reaction is about 5000° F. Actually, the molten metal reaches only 4500° F because of heat loss through the crucible and presence of pieces of metal included as an additional source of iron and of other alloying elements.

The molten metal from the thermit reaction in the refractory crucible is guided to the joint to be welded by a sand mold which is fastened around the work. By virtue of its superheat, the thermit metal melts a portion of the base metal with which it comes in contact. Upon solidification of this melt, the weld is completed. In pressure thermit welding, the superheated thermit is used strictly as a heating medium.

Brazing

The term *brazing* is applied to several processes using a wide variety of heating devices, types of fluxes, base materials, and joining alloys. Because they all involve the same basic method of joining, we feel justified in considering each a brazing operation. In each process, a molten non-ferrous filler metal or brazing alloy is flowed into a base metal joint which has been heated, but not brought to the melting temperature. In fact, the temperature of the preheated base metal need not be as high as the melting point of the brazing alloy. As the molten brazing alloy is applied to the base metal surface, intimate wetting takes place and the fluid metal spreads over the surface and penetrates any joints or openings. Upon cooling, a strong bond will be formed between the base metal and the brazing metal.

If we examine the bond between the base metal and brazing metal, we find that a certain amount of mutual diffusion has taken place at this interface to produce a zone or band of intermediate alloy composition. Brazing alloys are carefully formulated so that when they are applied to a particular type of base metal, surface diffusion or alloying quickly takes place, and the combined base metal and brazing alloy compositions form a low-melting intermediate alloy. The formation of this alloy is helpful in promoting easy wetting of the base metal surface.

Many different techniques are used for making brazed joints in cast iron, steel, stainless steels, copper, brass, aluminum, nickel, and other metals in similar or dissimilar metal combinations. The base metal may be heated by any one of a number of means: electrical resistance, induction, an arc, gas torch, and so forth. The base metal surface must be clean and free from oxide films which would hamper intimate wetting. Usually a flux is employed for this purpose, or the surfaces are precleaned and the heating and brazing operation is carried out in a furnace having a controlled atmosphere. The brazing alloy may be in several forms: filler rod, thin sheet suitable for preplacement in the joint, or as a powder for preplacement in the joint by dusting, swabbing or painting.

The compositions of the brazing alloys are particularly interesting and deserve our attention. The most popular alloys are either copper-base or silver-base materials, although alloys using a base of manganese or nickel have been developed for special applications. By alloying copper and silver with elements like zinc, tin, phosphorus, cadmium, and manganese, a variety of brazing alloys have been produced with melting points ranging from 1150° to 2000° F. At the lower end of this temperature range we find the silver brazing alloys, sometimes referred to as silver solders. In the range of 1600° to 1900° F we will find various kinds of bronze. Pure copper, which melts at 1981° F is also used as a brazing metal. The temperature employed in the brazing operation is generally above the melting point of the particular brazing metal being applied, often at a good *flow point* established for the alloy. Brazing with pure copper, for example, is carried out at approximately 2050° F.

Soldering

Soldering is closely akin to brazing inasmuch as it employs the same *method* of joining, but is considered a separate process because of distinct differences in the composition of the joining metals and their melting points. Solder metals are sometimes referred to as *soft solders* to avoid confusion with the silver-brazing alloys which some users erroneously call *silver solders* or *hard solders*. These soft solders, for the most part, are rather simple alloys of tin and lead. Each combination, of course, offers slightly different melting and freezing points, solidification characteristics, corrosion resistance, and mechanical properties. Antimony is often added for greater strength. Other elements like cadmium, silver, copper, and arsenic are sometimes added to secure particular properties. Practically all of the alloys melt at temperatures below 700° F.

Almost any metal base material may be joined by soldering. The procedure used is identical with that for brazing except that lower temperatures are employed. The base metal is preheated to a temprature below the melting point of the solder metal by any convenient means. Much

heating is done by conduction using a heated bar of copper as the heat source. This copper tool is commonly referred to as a soldering iron. Next, a flux is applied to the base metal surface to remove any oxide film which may be present. The composition of the flux will, of course, depend upon the kind of base metal. Copper brass, or plain-carbon steel requires only weak hydrochloric acid or paste containing ammonium chloride On the other hand, alloys like stainless steel which exhibit passive surfaces require strong acids like concentrated hydrochloric or phosphoric acid. Some fluxes contain metal salts which plate a thin film of metal on the base material to protect the surface from further oxidation during heating and promote good adhesion between the base metal and the solder metal.

When the solder metal is melted and dropped on the base metal, the spreading of the droplets or wetting of the base metal surface is called *tinning*. In a simple tin-lead solder, it is the tin which promotes the wetting and adhesion. The lead contributes nothing toward this end, but is valuable for its effect on the physical properties and mechanical strength of the solder metal. If we examine the bond between the base metal and solder metal as we did the brazed specimen, we would find that a small amount of diffusion occurs at the interface in this process also. The extent of diffusion will vary with the kind of base metal; in brass it is appreciable, in plain-carbon steel it is present only to a limited degree, and in stainless steel the zone of diffusion is almost imperceptible.

CUTTING PROCESSES

In addition to utilizing heat to join metals—an operation which we call *welding*—we also employ heat to cut or remove metals. Two principal methods of cutting are in commercial use today: *Arc Cutting* and *Oxygen Cutting*. Because both of these methods produce heat-affected zones in the metals on which they are used, it is only proper that we include them in a book on welding metallurgy.

Arc Cutting

This operation is carried out with the same kind of equipment as would be used for welding. A single electrode is used to strike an arc on the base metal to be cut. The work is grounded, of course, and the current for the arc is much higher than would ordinarily be selected for a welding operation. The cutting of the metal is simply a matter of melting a kerf through the section. Usually, a carbon electrode is used, however, it is often advantageous to use a metal electrode. For example, when cutting material with a high-chromium content such as stainless steel, a coated mild steel electrode is selected because the metal from the core wire dilutes the melted high chromium metal and facilitates its discharge from the kerf. The surface of the cut or kerf made by melting with an electric arc is, of course, inclined to be somewhat rough.

Oxygen Cutting

This method can be rightfully considered true *cutting* because it involves more than merely melting a kerf through the base metal. We sometimes hear the name *burning* applied. Actually, the process is a combination of burning (oxidation) and melting. Iron, when heated to a high temperature, will combine rapidly with oxygen. The reaction is exothermic, that is, heat is given off as the combination takes place. When operating a cutting torch, we arrange to have a portion of the base metal heated to a red heat (about 1500° F) and a stream of high-purity oxygen directed against it. Oxidation, or burning, of the metal begins almost instantly. The heat from the reaction is so intense that a considerable amount of adjacent metal is melted and flows away with the oxidized metal.

The conventional cutting torch is equipped with a tip which contains a number of orifices from which small oxy-gas flames burn continuously for heating, and a centrally located orifice from which a stream of high-pressure oxygen can be released by depressing a trigger. When operating the torch, a small spot on the base metal is first preheated to a bright red heat. When the steel is at this kindling temperature, the flow of high-pressure oxygen is started and an immediate reaction results. The kerf cut through the section will continue to advance as long as the oxygen stream is supplied. The heat from the oxidation reaction is so intense that often the oxy-gas heating flames are unnecessary once the operation gets under way. The molten material discharged from the kerf consists of approximately two-thirds oxidized metal and one-third unoxidized metal.

The oxygen cutting torch is an efficient tool on iron or plain-carbon steels; however, when alloying elements are added to steels, they may cause difficulty in cutting Some alloying elements are not as readily oxidized as iron, and when added to a ferrous base in substantial quantities, they limit the amount of iron available for reaction with the oxygen cutting stream. The elements nickel, copper, and cobalt are of this variety. Another kind of difficulty arises when alloying elements are added which are readily oxidized, but whose oxides are highly refractory. Chromium and aluminum are typical elements of this kind. When an appreciable amount of either of these two elements is present in steel being cut with the oxygen torch, their oxides quickly form a protective slag on the surface of the metal. This slag shield is so effective in hampering further oxidation that stainless steels, which contain 10 percent or more of chromium, cannot be properly cut with the oxygen torch. Instead of being a true cutting operation on stainless steels, the procedure is reduced to melting a pool of metal with the preheating flames and blowing it away with the high-pressure oxygen stream Obviously, these materials are not suited for the simple oxygen cutting process.

The difficulties involved in oxygen cutting metals and alloys which either do not contain a sufficient amount of oxidizable elements or form obstructing films of refractory slag have been largely overcome through the development of these three new oxygen torch cutting methods:

Flux-Oxygen Cutting—This process is conducted using regular standard oxy-acetylene cutting torch equipment. Only one additional piece of equipment is required, that is, a flux feeding unit which injects a powdered chemical flux into the hose line carrying the high-pressure cutting oxygen. This flux disposes of the viscous chromium oxide slag which ordinarily forms on the heated metal surface and hampers the cutting action. This process was developed particularly for cutting stainless steels. While it will also cut cast iron, another metal which resists cutting, it is not applicable to metals like copper, nickel, Monel, Inconel, and so forth, because these materials do not contain enough oxidizable iron, manganese, or chromium.

Oxygen-Arc Cutting—This tool is capable of severing every metal or alloy, even those which do not contain oxidizable elements. The operation is performed with a tubular, metal electrode, flux coated, which permits an operator to hold a manual arc and at the same time feed a stream of high-pressure cutting oxygen through the electrode. Intense heat is supplied by the arc. The tubular electrode core wire of steel supplies the kerf with iron which is oxidized to generate additional heat.

Powder Cutting—This process uses oxy-acetylene cutting torch equipment, supplemented by a unit which feeds iron-rich powder through a tube to the torch tip where it is directed into the oxygen cutting stream. The powder must be carried through the tube by an atmosphere of compressed air or nitrogen for if compressed oxygen were used, or if the powder were injected into the oxygen hose line, a flashback probably would occur. After the powder enters the oxygen stream, it burns and produces considerable heat. The viscous refractory slag films which form on some metals are removed by a combination of melting and fluxing with iron-rich oxide. This process works well on stainless steels. However, on material containing little or no oxidizable elements, the cutting is more of a melting operation with heat being supplied by the oxidation of the powder.

SUGGESTED READING

Welding and Its Application, by B. E. Rossi, 1941, McGraw-Hill Publishing Company.

Procedure Handbook of Arc Welding Design and Practice, Eighth Edition, 1945, Lincoln Electric Co., Cleveland, Ohio.

The Oxy-Acetylene Handbook, 1943, The Linde Air Products Co., New York, N. Y.

Theory and Practice of Arc Welding, by R. J. Sacks, 1943, D. Van Nostrand Company, Inc.

Resistance Welding Manual, Revised Edition, 1946, Resistance Welder Manufacturer's Association.

Standard Welding Terms and Their Definitions, 1949, American Welding Society.

Welding Handbook, Third Edition, 1949, Chapter 1, American Welding Society.

Welding Conserves Steel

Welding saves steel in structural plate girders, trusses, bunkers. It eliminates noise which is important on some applications

by T. R. Mullen

OUR experience as structural-steel fabricators reveals that the available supply of structural steel can be made to go much further through the use of welding. We also believe that the building industry has not yet capitalized on the full economy offered by welding and that current shortages of steel makes its adoption increasingly attractive.

In the past, use of structural welding has been curtailed by lack of technical data and experience. Today, through the AMERICAN WELDING SOCIETY and the American Institute of Steel Construction, ample information is easily available to every architect and engineer. In addition, many fabricators acquired valuable experience during the last war.

The labor picture also has changed. Skilled riveters apparently are in short supply; whereas, because of the training received in private industry and in the armed forces, there are many more men qualified to weld. Furthermore, research has yielded welding equipment, such as automatic welders, stud welders and squirt welders, that has decreased the importance of the operator element in obtaining sound welds and increased the efficiency and reliability of structural welding.

Although welding does not lend itself to all types of structures, substantial savings in tonnages can be effected when it is used in building up such structural elements as plate girders (Fig. 1), trusses (Fig. 2) and coal bunkers. For example, a short time after welding was permitted under the new building code in New York City, our company obtained contracts for three public schools in which we desired to substitute welded plate girders and trusses for the riveted construction shown on the contract drawings. To get permission of the Board of Education, a part of the saving was given back to the city in the form of a credit on the contract price. The credit amounted to about $1000 for each school and the company profited a like amount

Fig. 1 Welded plate girder, 66 in. deep by 126 ft. long, for a bridge over the Willimantic River, Conn.

T. R. Mullen is President of the Lehigh Structural Steel Co., Allentown, Pa.

This article is reprinted from *Engineering News-Record*.

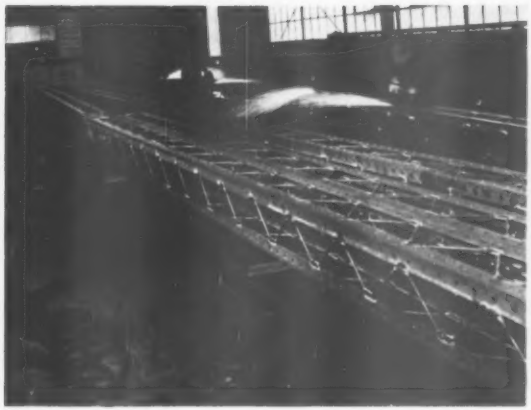


Fig. 2 Switchyard trusses for Consumers Power Co., Jackson, Mich., were fabricated by welding

Fig. 3 Columns for a garage in Miami were shop spliced by welding. Holes were punched only in beam seats

by this change from riveted to welded construction. This credit, about 1% of the amount of the steel contract, resulted from change in design of only five plate girders in each school.

A number of structures throughout the country prove that traditional beam and column work, with its simple connections, also can be welded. The advantage of a welded beam and column job lies in the saving of metal, not total cost.

The total cost for a welded structure with beam and column connections, such as the New York multistory buildings, is usually about the same as that for bolted and riveted construction. The total tonnage of the structure is less because welded connections use less material and thus save precious steel. But, there is no over-all reduction in cost because the saving in metal is slight, and this saving is used up by a slightly increased labor cost in the shop welding.

These statements are true when welding is substituted for riveting at such points in the structure where riveting would be a requirement of the engineers of the building department. We do not imply that we can substitute welding for field bolting at the same cost, but we can, and frequently do, substitute welding for riveting in the field and save money.

For such structures as additions to hospitals, schools, court houses or other buildings where the daily business must be carried on during construction, field welding has the advantage that connections can be made quietly as compared to riveting operations. Quietness in making alterations was a distinct advantage in additions that we made to the Providence Court House in Providence, R. I., many years ago.

Within the past 10 years, we have constructed additions to Bellevue Hospital connecting new steel to the old, by means of welded connections, which we suggested to the engineers as an alternative to the design originally shown. To have driven field rivets for this hospital job would have necessitated breaking the brickwork right out into some of the wards. Our suggestion merely required that the face brick covering the columns be exposed to permit us to weld connection angles to the old steel. Our suggestion was accepted and this was done. At the Jersey City Medical Center, we fabricated and erected, all by the welding method, a 21-story building amid the existing hospital group.

There can be little argument as to the advantages of this method when the welfare of the patients is concerned. These features are worthy of consideration aside from the cost of the operation.

Welding permits compact connections, which minimize and sometimes altogether eliminate connection material. An example of this is a bottom-chord panel point of a truss, in Fig. 4, in which there is no gusset plate. This characteristic has manifold implications.

For example, welding can play a vital part in erecting the tall towers needed for telecasting. These structures demand heavy footings and anchors. Since, by the use of welding, large anchoring forces can be applied to a small area, much material may be saved and

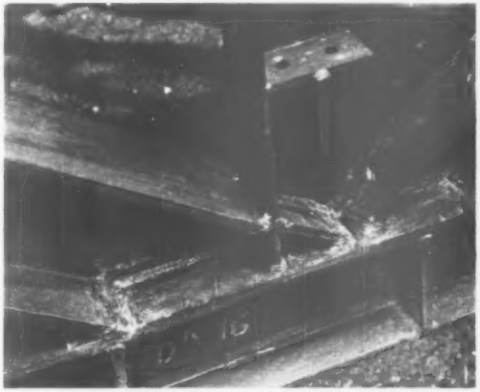


Fig. 4 Butt welds hold the H-beam members of a welded roof truss at Electronics Park, N. Y.

design detail simplified by this method of attachment.

Elimination of rivet heads and connection material may result in more attractive structures. The plate girder in Fig. 1 is an example of the smooth surface and outline that can be obtained for highway bridges by welding. Also, as reported to us by bricklayer supervisors, brickwork covering a welded structure is simpler to lay and less costly, because such projections as rivet heads, clip angles and gusset plates are eliminated.

There is also a saving in shop fabrication, since handling of pieces is a large portion of fabrication cost and there is less weight and fewer pieces when welding is used. In many cases also, detail working drawings can be prepared in less time on welded work than on riveted, provided the structure has been designed for welding from its inception.

In fact, to obtain the utmost economy from welding, the designer should decide at the very start of his calculations whether to use welding or riveting. Much more material generally can be saved in a design intended primarily for welding than in one that may be either welded or riveted.

Costs are greatly increased when the design requires both welding and riveting on the same member. When the job is welded, it goes through the welding shop. If rivets are to be driven, the work must be brought into another part of the plant, and the extra handling runs up the cost.

By proper design of connection details, certain shop operations may be eliminated. For example, the columns in Fig. 3 have been shop spliced without providing holes in the main elements, and the field-connection holes for the beams are in the light beam seats. This design eliminates punching and drilling of the heavy column sections and in many cases, the laying-out operation as well. As a result, the amount of handling of heavy pieces in the shop is materially reduced, and with it fabrication costs.

Attention is also drawn to the fact that structural shapes seldom conform exactly to handbook dimensions. In designing connections, therefore, the engineer should allow for mill tolerances, which are to be added to or subtracted from the handbook sizes, if the parts are to fit properly.

It is hoped that the suggestions offered here will encourage more effective use of welding. Thereby, we can make the most of our opportunity to conserve steel by welding, at a time when its supply is critically short.

Statement of the Ownership, Management, Circulation, etc.

REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

OF THE WELDING JOURNAL, published monthly at Easton, Pa., for October 1, 1949.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William Spraragen, who, having been duly sworn according to law, deposes and says that he is the Editor of THE WELDING JOURNAL and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily, weekly, semiweekly or triweekly news paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Acts of March 3, 1933 and July 2, 1946, (section 537, Postal Laws and Regulations) printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of — Post Office Address

Publisher, American Welding Society, 33 W. 39th St., New York 18, N. Y.

Editor, William Spraragen, 33 W. 39th St., New York 18, N. Y.

Managing Editor, William Spraragen, 33 W. 39th St., New York 18, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

American Welding Society, 33 W. 39th St., New York 18, N. Y.
G. N. Sieger, President, 1165 Harper Ave., Detroit, Mich.
M. M. Kelly, Secretary, 33 W. 39th St., New York 18, N. Y.
R. S. Donald, Treasurer, 50 Church St., New York, N. Y.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)

None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is 10,000 (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.)

WILLIAM SPRARAGEN, Editor.

Sworn to and subscribed before me this 19th day of September, 1949.

FRANCIS J. MOONEY
Notary Public, State of New York
No. 31-2754750
Qualified in New York County
Cert. filed with City Register, N. Y. Co.
Commission expires March 30, 1951

Flame Straightening, Forming and Cleaning Structural Steel

The structural steel industry benefits from the use of the oxyacetylene flame in straightening and forming steel parts by local heating. The flame is also beneficial for cleaning structural steel preparatory to painting

by F. H. Dill

SINCE the introduction of the oxyacetylene cutting torch and its companion, the welding torch, to the structural fabricating industry over 40 yr., there has been ever-increasing use of the oxyacetylene flame to perform old tasks more easily and to accomplish work that is beyond the reach of other tools. Local heating of parts for mechanical straightening or hot bending is a use that developed because it could save time. Straightening complicated pieces and assemblies solely by ingenious local heating, and the corollary process of forming or cambering steel parts by local heating, save time and cost and accomplish results that could not be attained otherwise without tremendously large and costly machinery. Cleaning structural steel with oxyacetylene flames before it is painted creates uniquely beneficial characteristics in the paint film and its adherence to the steel.

The most obvious advantages of the oxyacetylene flame are its portability, and its ability to reach places that are inaccessible to other tools. In the structural fabricating industry where the finished structures, their individual members and even the parts of members, are large and heavy, the scheme of bringing tools to the work is always attractive. The very general use of portable pneumatic and electric tools in both the shops and the field erection work of the industry exemplifies this. Under such circumstances the extremely portable oxyacetylene flame has had increasing use in the structural steel industry as needs for it have arisen and as men have invented new applications and proved their merits.

Fortunately most of the steel used for bridges, buildings and similar structures is not harmed by the thermal shock of steep temperature gradients within it. It can, therefore, except when it is very thick or very cold, absorb the full force of the intense oxyacetylene flame. This fact is recognized now in specifications that govern the fabrication of bridges and buildings and it is becoming less often necessary to demonstrate to engineers that application of the flame does not damage the steel metallurgically.

F. H. Dill is Welding Engineer, American Bridge Co., Ambridge, Pa.

This paper was presented before the Annual Meeting of the International Acetylene Association, Pittsburgh, Pa., April 25-26, 1949.

Heating

An early and still important use of the oxyacetylene flame in structural work is for heating steel to visible red heat so it can be straightened with hammer blows. This permits parts, such as connection angles and light flanges that stand out from large members and are often bent in handling, to be straightened without moving the piece to a machine. It saves both time and expense. A similar application appears in the final setting to accurate dimensions of pieces that have been bent in presses. The flame eases and speeds the work.

A more recent use of the oxyacetylene flame has been for locally heating steel to hot bending temperatures preparatory to bending in a press or by other mechanical means. This application, which is possible where there is a plentiful supply of low cost acetylene, pits the rapid heating of the oxyacetylene flame against the slower more soaking heat of less expensive fuels burned in torches or in open top, slot-type furnaces. Heating time is reduced and sharper bending and more accurate location of bends can be attained. Heating time is reduced directly by the rapid heating rate of the intense oxyacetylene flame, but there is further saving of time and fuel because a short heating time minimizes the loss of heat into contiguous metal that it is not necessary to heat.

Sharper bending a more accurate location of bends result from the ability to heat only the metal which must be deformed in bending. It is very important, however, in this use of the oxyacetylene flame to heat sufficient metal to permit bending without excessive reduction in the thickness and width of the piece being bent. For unsymmetrical sections this demands heating of triangular- or trapezoidal-shaped areas.

Another very important precaution for this method

of heating for bending or for any other scheme of local heating is to avoid heating to temperatures of 400 to 700° F. any steel that has been severely cold-worked, as by cold-forming, punching or shearing. Inattention to this precaution can allow the development of strain-aging and consequent brittle fracture of the steel. An example of this can be cited from the records of a large fabricating shop in the fracture of several 8 x 8 x $1^1/_8$-in. flange angles for girders. The angles were punched and then curved by cold-forming before they were torch-heated for making a sharp angular bend. They broke in brittle manner through punched holes about a foot from the center of the bend while they were being fitted and assembled with the web and other parts of the girders.

Heat Straightening

The wide acceptance of flame cutting and welding as practical methods for the fabrication of structures has provided great impetus to the use of the oxyacetylene flame for straightening and forming steel. When rivets are used for connecting the elements of a structure there is seldom need for straightening or fairing completed members or assemblies. Flame cutting and welding, however, both involve intense local heating of the steel and inherently cause shrinkage of the metal. It is natural to fight fire with fire and the intense oxyacetylene flame has come into use for creating balancing shrinkages that produce straight members and fair structures. Technical studies have explained how shrinkage develops from upsetting heated metal against the restraint of surrounding cold metal so that it is thicker and shorter after it has cooled. Workmen with torches in their hands have developed skills that make practical use of this phenomenon.

During the tremendous wartime construction of ships the fairing or flattening of plating by local heating received much attention. Checkerboard patterns of spots and zebra-like stripes were common sights in the shipyards. They displayed the shipbuilders' solution to the problem of eliminating the buckles that formed in rectangular panels of thin plating that had been shrunk at the boundaries of the panel by the welding which attached the plating to the skeleton of the ship. Heating spots about an inch in diameter to visible red heat on a checkerboard pattern in the buckled panels created an accumulation of small shrinkages which, in total, equalled the weld shrinkage around the borders of the panel and drew it flat. Some shipyards preferred lines of heat to rows of spots and some yards used both. Often the cooling of the heated metal was accelerated by directing small jets of water or air-water sprays against it to speed the work and to increase the shrinkage of each spot. In all of the work, however, the man using the torch had to judge the "temper" of the buckle and skillfully fit the amount and location of heating and accelerated cooling to the individual conditions of each panel.

In the fabrication of large structures and structural members by welding there are often detail or over-all distortions from the dimensions that the completed pieces are required to have. The pieces are usually too bulky to fit into presses for correction of their dimensions and many of them are beyond the reach or capacity of mechanical methods of straightening. Practical experience has shown that heating to produce shrinkage along lines parallel to and opposite to the welds permits the necessary correction to be made quickly and easily and without moving the structure or member far out of its usual path through the shop. Girder flange plates $2^1/_2$ in. thick, for example, that are curled by the welding that connects them to the girder web can be made flat and square with the web by heating them along the center of their outer face with a large multi-flame oxyacetylene torch moving along the girder at a speed of 6 to 12 in. a minute. Connection plates at the ends of beams and trusses can be similarly straightened and the flanges of wide-flange beams can be made square with the web by judicious heating. Experience in a least one plant has shown that the shrinkage effects of local heating can sometimes be used to straighten plates that would break if they were straightened by hammer blows or other mechanical means. Contrariwise, it has also been demonstrated that excessive or improper application of heat shrinkage can tear the steel apart.

Beam Cambering

Many persons may be surprised to learn that expansion of the nation's highway system has promoted a very large use of the oxyacetylene flame. The motorist's demand that small bridges be practically unobservable as he crosses them has engendered the development of bridges made of long rolled beams cambered or curved vertically to fit the contour of the roadway. The cambering of large beams that is offered by the steel mills is not accurate enough for this use and it often does not fit the dimensions that are required by the engineering designs. It was natural, under these circumstances, for shop men familiar with the power of oxyacetylene flame to apply it to the job of providing accurate camber that could not be obtained by other methods.

The basic principles of cambering beams by heat shrinking are quite well established. The beam is set upside down with supports under its ends only. Heat is then applied to the uppermost flange (the flange which will be the bottom flange in service). The beam first arches upward under the influence of the expansion of heated metal, but as the flange cools the shrinkage that accompanies local heating will shorten the flange and the beam will curve downward toward the camber that is desired. Skill and experience are required to judge from the behavior of the beam, as it is heated, the amount of heating necessary to obtain the specified camber.

An early method of heating the flanges of beams that were to be cambered was to heat several zones about 3 in. wide across the entire flange so that the steel was at bright red heat throughout its thickness. In this

scheme the weight of the beam was a major factor in upsetting the heated metal and the number of zones heated largely governed the amount of camber produced. The cambered shape was a broken curve of straight segments with a small but sharp bend at each heated zone. The scheme was satisfactory for cambering beams with very wide flanges that were only 14 to 16 in. deep, but it was not effective for larger beams, even when weights were set on the beam to increase the upsetting of the heated zones. It has been found, however, that this general idea can be made effective for large beams if the heated zones of the flange are extended over a distance equal to half the depth of the beam and if the web at each zone is simultaneously heated in a triangular area extending from the heated zone of the flange to the center of the web. This is still a fairly common method of heating beams to camber them but it is rather slow and expensive.

Searches for faster and more economical schemes for heating the flanges of beams and for means of producing smoothly curved cambers have led to the use of longitudinal heating of the beam flanges to subcritical temperatures. Initial trials of this scheme were made with extremely large multiflame heating torches and with the heated zones intermittent along the length of the flange. Recent work, however, has been with torches of about 250 cu. ft. per hour capacity making continuous lines of heat. Control of the amount of heat supplied is gained primarily by skillful adjustment of the speed at which the torch travels, but secondary control is had from adjustment of the size of the flames and the distance from the torch tips to the work. The number and arrangement of the torches across the beam flange is chosen to suit the dimensions of the beam being cambered.

One shop has recently cambered a large number of 16-in. wide flange beams with $2^3/_4$-in. camber in 40 ft. Another shop has obtained a camber of 11 in. in 36-in. wide flange beams, 80 ft. long. Cambers of $1^1/_2$ or 2 in. can be put into beams with less than an hour's work by a single workman. Camber or curvature of only part of the length of a beam can be provided if it is needed and, by heating the upper and lower sides of each flange simultaneoulsy near one edge, beams can be curved laterally to fit engineering or architectural requirements.

Flame Cleaning

The development of new types of paint vehicles 10 to 15 years ago was a prime factor in creating a new use for the oxyacetylene flame. The new paints had different drying characteristics than the paints traditionally used in the structural industry and they required more thorough cleaning and drying of the steel surfaces before the initial or prime coat of paint was put on. Sand blasting was tried, but it was very expensive and it did not provide the extra dryness that was needed. Experiments with steel that had been warmed just before it was painted showed promising results and the oxyacetylene flame, with its inherent portability and flexibility, was put in use to provide similar conditions on steel in structural shops. Special comb or ribbon burners were developed, with particular attention being directed to providing the highest possible flame velocity and intensity. Trials of other fuel gases showed that only the oxyacetylene flame could accomplish the desired results. It was found that the cost of flame-cleaning steel in preparation for painting was less than half that of sandblasting. The nuisances of sandblasting were eliminated and a thoroughly dry and warm surface was presented for the prime coat of paint.

Specifications which define flame-cleaning as a unique process involving the following four separate operations have been adopted by the American Institute of Steel Construction so that the process can be distinguished from descaling processes and can be held to accomplishment of its intended results in commercial use:

1. Oil, grease and similar materials are to be removed with solvents.
2. The surfaces of the steel are to be cleaned and dehydrated by the passage of the special oxyacetylene flames. (This operation drives adsorbed moisture from the surfaces and also breaks away partly loosened mill scale and rust.)
3. The surfaces are to wire-brushed and then swept with soft brushes to remove loosened scale, dirt and dust.
4. Paint is to be applied promptly and while the temperature of the steel is still above that of the surrounding atmosphere.

The paint on bridges that have been flame-cleaned in preparation for their prime coat of paint has given good service during the last 10 yrs. and appears to substantiate the claims of merit that are made for the process.

Conclusion

All of these uses of the oxyacetylene flame require large amounts of acetylene and they are most economical where there is adequate supply of low-cost acetylene from piped distribution systems. Some of the uses demand such volumes of the gas that they are not feasible where the acetylene must be taken from cylinders. The availability of low-cost oxygen from piped distribution systems enhances the value of the various processes and makes them practicable in commercial work.

The uses of the oxyacetylene flame that have been reviewed are those apart from welding, flame cutting and the flame-softening of flame-cut edges of hardenable steels. There has not been any attempt to list all the applications that are made in straightening, forming and cleaning structural steel, but it can be remarked, in conclusion, that use of the oxyacetylene flame provides the structural fabricating industry with a tool that has an unsurpassed combination of portability, flexibility and power. Use of the flame has proved economical, and it accomplishes many tasks that have never been done by other equipment and processes.

New Flash-Welding Techniques

These techniques overcome important metallurgical problems in aluminum, greatly increase aluminum alloy applications, reduce weld-finishing requirements and cut fabricating costs

by Chas. Bruno and G. W. Birdsall

ALUMINUM is today being used in greater volume than any metal other than steel because (1) of its ready availability in all forms, (2) its increasingly more attractive economic position, (3) its many important advantages—natural attractive appearance, immunity to red rust, ease of fabrication, light weight and high strength. In fact, it can be said that aluminum that reached its prominent place in today's metal picture because it is possible to add alloying elements, to heat treat and to cold work the material *to increase the low strength of pure aluminum more than 14 times* (5000 psi. yield strength for 28-O against 71,000 psi. for 75S, typical values). However, to date the use of high-strength heat-treated aluminum alloys has been held back because of the necessity of heat treating such fabrications *after* welding. The reason, of course, is that structures welded from heat-treated aluminum alloys experience a significant and costly reduction in strength due to an indeterminate amount of annealing that occurs in the heat-affected zone alongside each weld. To prevent this strength loss, it is necessary to heat treat the completed assembly after welding. This is not always possible or economically feasible.

The net result of this fabrication difficulty has been that the use of high-strength aluminum alloys, heat treated at the mill (most economic), has been retarded unnecessarily and many applications where they would otherwise be the preferred material have been crossed off the designers board simply because it was not practicable or too costly to heat treat the completed assembly after fabrication. Now, however, the first improved flash-welding technique, described below, permits production of welded joints in these high-strength aluminum alloys in the heat-treated condition without loss in strength. The section in this paper on *Economic Significance* analyses further the importance of this development.

G. W. Birdsall and **Chas. Bruno** are connected with the Editorial Department, Reynolds Metals Co., Louisville, Ky.

INFLUENCE OF JOINT THICKNESS

To understand the thinking back of this development, it is important to examine carefully the effect of joint thickness on joint strength. It may not be realized but joint thickness is possibly the most important single factor (other than proper fusion) on joint strength, as is shown in the following paragraphs.

This fact can be demonstrated by making butt joints between two steel bars with ordinary 50% lead, 50% tin soft solder. Tin the two ends to be joined, separate them by about an inch and fill the intervening space with solder. Then pull the joint in a tensile testing machine. The solder in the joint will neck down and the joint will show a maximum tensile strength approximately equal to that of the solder (6100 psi.).

Now repeat the experiment but use a shorter space between the two bar ends, say $^1/_{16}$ in. It will be found that the joint strength has increased appreciably. Repeat with still shorter distances, further increases in joint strength will be obtained. Finally, just tin the two surfaces, then wipe them together while hot to squeeze out all the solder possible, applying considerable pressure. If the bar ends were ground perfectly flat and smooth an amazing thing will be found—the joint strength has increased to a value several times that obtained at first, *yet it is still made with soft solder.*

That is a demonstration of the importance of joint thickness!

ELIMINATING HEAT-TREATING PROBLEM

The principle explained in the foregoing has an important adaptation in flash welding high-strength aluminum alloys. The new technique explained hereafter now makes it possible to produce flash welds measuring less than one-thousandth of an inch across the weld zone. Micrograph, Fig. 1, shows such a weld.

The aluminum on either side of this extremely thin weld is unaffected as is shown by uniform grain size right up to the extremely thin line representing the actual weld. This is extremely important for it means that such a joint can be made in heat-treated, high-

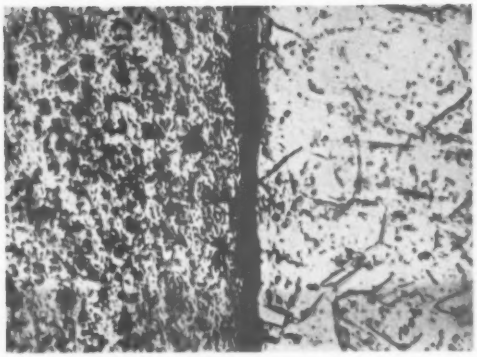


Fig. 1 Micrograph of percussion-welded tubing joint shown in Fig. 2

Weld zone (dark line) is 0.0004-in. (4 ten-thousandths) across. Note grain structure alongside weld is completely unaffected except for small amount of cold work (flattening of grains) in the aluminum (darker portion) caused by the high pushup force (20,000 psi.)

strength aluminum alloys without any reduction in strength in the metal adjoining the weld and, since the weld itself is so small, the strength of the joint is exceptionally high, practically as strong as the adjoining parent metal.

Development work now being done with tubing for refrigeration applications indicates this type of welded joint has great significance. It permits joining heat-treated aluminum tubing to plain tubing; aluminum tubing can be joined directly to copper, stainless steel, Monel or other alloys without regard to the dissimilar metals in the joint because the fusion zone is so small that practically no intermixing occurs and no change in grain structure whatever. Thus, all types of condenser and expansion coil structures for refrigeration equipment can be fabricated easily, opening up an entirely new range of design possibilities.

NO FLASH

Of utmost importance in refrigeration work is the elimination of interior flash. By putting a very slight hollow "cone" shape on the abutting tub ends, it is possible to force all flash to the outside, leaving only a few loose particles on the inside that can be blown out easily with compressed air. This is a most valuable feature as can be appreciated when considering the difficulty of removing interior flash at a joint in the center of a 20- to 30-ft. length of tubing—simply not practicable. So eliminating interior flash is a real money-saving feature. Not only that, but it makes practicable for the first time such assemblies of dissimilar tubing as aluminum and other metals.

Joint designs using mechanical connectors are not very satisfactory for refrigeration due to leakage which is a most serious problem. The new improved flash welds, however, give no trouble from leakage, being perfectly gas tight as shown by extensive testing.

"PERCUSSIVE" WELDING

The above joints are made by an improved flash-welding technique that somewhat resembles the Vang Percussive Welding Process. According to the *Welding Handbook*, percussive welding is "a resistance-welding process wherein a relatively intense discharge of energy and the application of high pressure (usually a hammer blow) occur simultaneously or with electrical discharge occurring very slightly before the application of the pressure of the hammer blow."

Several variations of percussive welding have been developed through the years. First, it was used almost exclusively for butt welding small diameter wires as in electric light bulbs, using a low-voltage condenser as the energy source and a mechanical system that brought the two parts to be joined together to start the flow of energy, separated them for arcing and then joined them by the hammer blow.

Next the condenser was replaced by a transformer whose primary was connected to a direct-current source. Upon opening the primary circuit, collapse of the electromagnetic field produced large currents in the secondary circuit containing the work, somewhat on the order of the familiar stored-energy spot welder now in wide use.

The system was still complicated, however, by the mechanical requirements for establishing contact, separating, and then hammering together the two parts being welded. So a further advance was made in the process using condensers charged to a sufficient voltage to break down the gap between the parts and thus eliminate the necessity for touching and then drawing them apart.

Now further improvements have been made which can not be fully disclosed here because of the present patent situation. However, it can be said that stored energy welding current is used, carefully metering the exact amount of energy discharged during the weld and thus permitting close control of amount of metal melted at the weld interface.

Also, in order to obtain the impact desired immediately after application of the welding current, the work is hammered together by using the energy stored in an

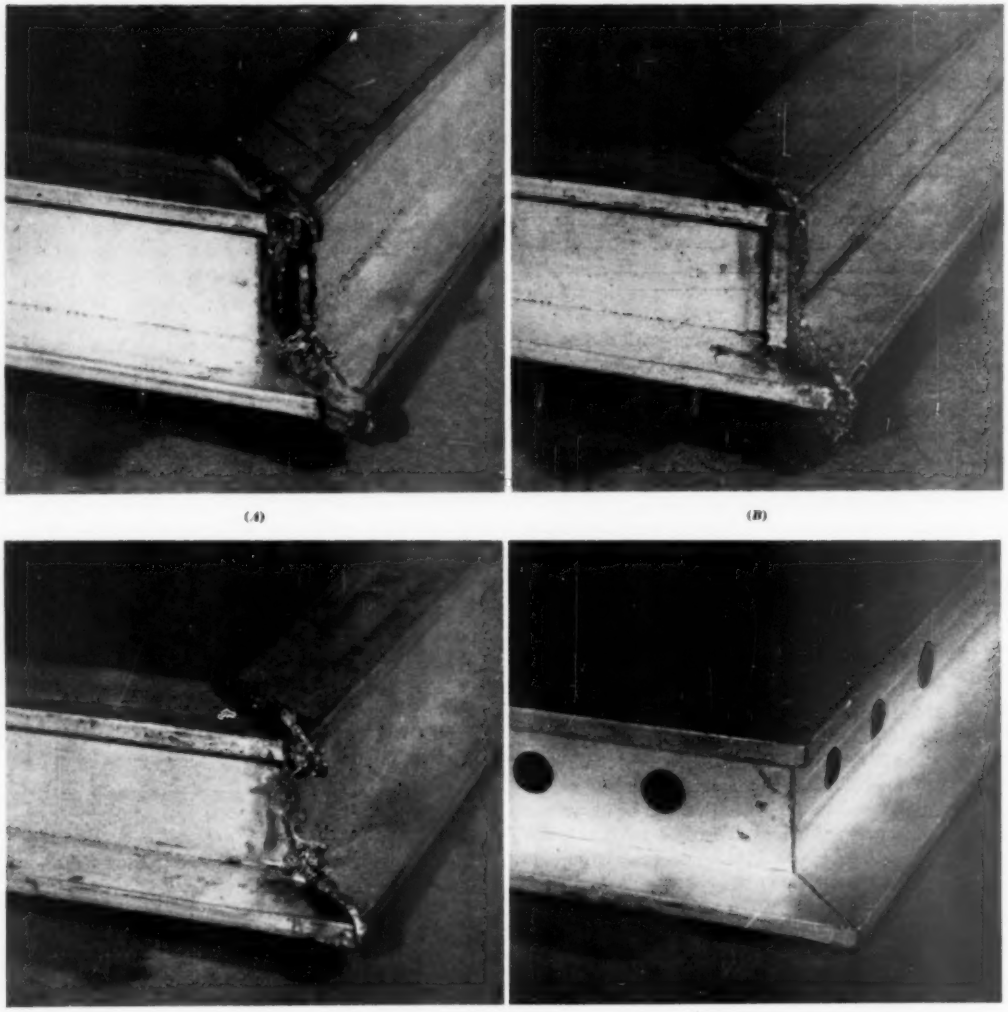
Fig. 2 Enlarged view of percussion-welded joint between copper and 38-H14 aluminum tubing, 5/16 in. O.D., 1/16-in. wall

Note complete absence of flash. Interior also is clear except for few small globules easily blown out with compressed air.
Weld was made with 120 mfd. of condensers charged to 2200 v., discharging to the weld through a 1000:1 ratio step-down transformer giving approximately 80,000 amp. at 2.2 v. during the 1-sec. flashing period, during which about 1/4 in. was burnt off end of each piece

air cylinder whose piston is connected to the moving electrode. The piston is held back until the moment of impact by means of an electric solenoid. Welding control circuits open the solenoid circuit at the moment of impact so air pressure then is free to ram home the piston and moveable electrode connected to it.

Such a system provides precise control of every factor involved in the welding operation. Amount of metal melted is controlled by amount of energy stored up and dissipated in making the weld. Movement of the electrodes and pressure exerted prior to hammer blow can be controlled by usual methods. Hammer blow timing can be precisely controlled by electronic circuits connected with the actual application of welding current, so can be applied at any desired point succeeding application of welding current. Strength of hammer blow can be adjusted easily by selection of air cylinder and pressure maintained therein.

The result is a precision flash-welding machine. This is the type of machine on which the tubing welds shown in Figs. 1 and 2 were made. Note that weld zone measures only 0.0004 in. (less than half a thousandth of an inch). Note, too, that original gram structure adjacent to the weld is not changed. Some slight



(*A*) (*B*) (*C*) (*D*)

Fig. 3 Stages in development of improved miter welding technique

(*A*) First step: usual commercial practice. Upset metal extends about 1/4 in. across weld zone. Makes weld difficult to finish. (*B*) First attempt to reduce flash by setting dies closer together. Note how dies have compressed most of the flash; weld zone still quite large. (*C*) Much improvement results from relieving dies by cutting back ends to open up 60° angle, permitting closer grip on work and exertion of a "pinching" action to cut off extruded flash. (*D*) Here we have reduced weld zone to a mere line. Now there is no upset metal outside weld zone at all. What little flash remains is all but cut off by the dies

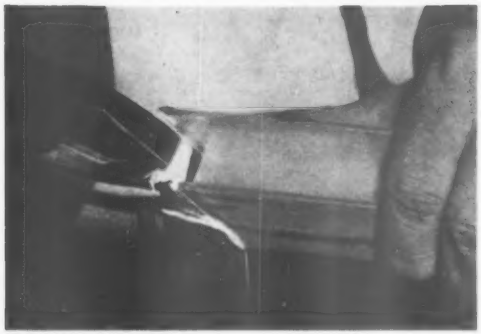


Fig. 4 This shows how what little flashed metal remaining on the weld can easily be knocked off with a pair of pliers. Finishing this weld requires very little work

cold working of the aluminum (darker section) has occurred from the hammer blow as evidenced by the more compact grain structure next to the weld. There is no internal flash on these welds.

Sufficient power is stored in high voltage condensers to permit welding parts up to $^1/_2$ sq. in. in cross section. This means that tubing up to about 2 in. O.D. in normal wall thicknesses can be welded by this method. Also extruded shapes in any cross section shape desired can be welded as long as the cross section area is less than $^1/_2$ sq. in. Of course, larger cross sections can be handled by simply adding more capacitors.

REDUCED WELD FINISHING

Another variation from conventional flash welding is utilized to practically eliminate the problem of flash removal. In many joints, flash removal is a simple problem as the periphery of the weld cross section is some simple geometrical shape, such as a rectangle when flash welding rectangular bar.

However, when welding many extruded aluminum sections, removing flash is a long, tedious and expensive process because of the difficulty of getting at the many surfaces represented around the periphery of the weld. For example, in miter welding certain extruded aluminum frame members, the sections joined roughly resemble a "z" stretched horizontally so the slanting member becomes vertical but with "overhangs" on top and bottom members extending past this vertical member (Fig. 5). When miter welded, there are actually 11 different surfaces at each joint to be cleaned if all flash is to be removed.

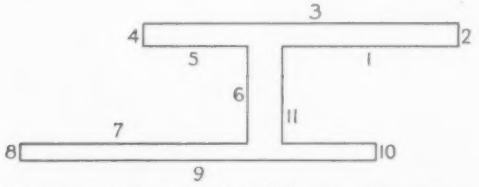


Fig. 5 Cross section of extruded aluminum frame members joined by flash welding in Fig. 3, showing surfaces to be finished after miter welding

This flash removal operation could easily become so expensive as to greatly increase the finished cost of the fabricated part. So it became imperative to develop some means of reducing the flash.

Figure 3 shows successive stages in a project aimed at eliminating the problem of flash removal. At *A*, note that upset metal extends for about $^1/_4$ in. across the weld zone. This creates a tremendous amount of work in finishing off the welded joint, is especially difficult to get at on the interiors.

We were informed that this was the usual amount of upset and that this was even better than obtained commercially in many plants. However, it was a long way from the weld desired.

At *B*, Fig. 3, we have the result of first attempts to reduce flash. Note upset is considerably smaller, although the weld zone itself is still quite wide. Also amount of flashed metal is still considerable. Note dies have "squeezed" or compressed most of the flash.

At *C*, much improvement is evident—smaller weld zone, less upset, reduced flash. Here the dies have been relieved by cutting back at about 60°, permitting a closer grip on the work and the exertion of a "pinching" action to pinch off the extruded flash.

At *D*, the weld zone has been reduced so much there is no upset metal outside of weld zone at all. The flash has been practically cut off at the surface of the weld by the close pinching action of the dies.

The flashed metal remaining is easily *knocked off* with a pair of pliers (Fig. 4). There remains practically no work to be done in finishing this weld. It is easy to see how this weld greatly reduces weld finishing costs.

How was it done?

ADVANCED THINKING . . . ADVANCED RESULTS

The success of this project can be attributed largely to a little unconventional thinking on the problem.

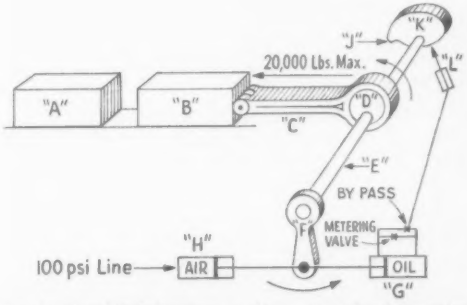


Fig. 6 Simplified diagram to show principle of operation of new type flash welder with high-speed pushup utilized to produce improved miter welds shown in Figs. 3 (D) and 4. See text for explanation of operation

Why should we tolerate a wide weld zone and large amount of flash? Precision controls now available on latest type flash welders largely do away with inconsistent results formerly obtained.

Extensive flashing periods and comparatively slow pushups with weld current remaining "on" during push-up are no longer required to compensate for control inconsistencies.

Why not reduce flashing period to the very minimum to heat the metal to fusion, and reduce the pushup to a hammer blow to obtain the advantages of percussive welding, cutting off the welding current at the instant of the hammer blow?

Work along these lines is responsible for the excellent results shown at *D*, Fig. 3, and in Fig. 4 where flashed metal fin is so thin it can be removed completely and quickly with a pair of pliers as shown. Note that weld zone has been reduced to only a few thousandths of an inch (0.006–0.010 in.).

Most of these advantages are attributed directly to the speedy, powerful pushup employed as this is so fast it resembles a hammer blow. It forces out of the weld most of the molten metal; leaves only an extremely thin sheet. This in turn tends to thin out the flashed metal as it leaves the weld.

Most important feature is that the dies were clamped closer and closer to the weld in the series of samples shown in Fig. 3. Clamps were "relieved" at tips by grinding them back to give about a 60° opening.

Also they were set as close to the weld as possible, only a small fraction of an inch apart. This means they practically "pinch" off the flash during the fast pushup.

Of course, using die clamps, working so close together as this is only possible when the welding machine has precision controls to prevent burning and to assure repetition of the desired cycle of operations during production of each weld.

Fig. 8 Miter welder in operation

These welds are produced on one of the latest type flash-welding machines provided with a new and unusual system of control and a "hammer blow" type pushup. Figure 6 is a simplified operating diagram to show method of control, main operating elements, etc.

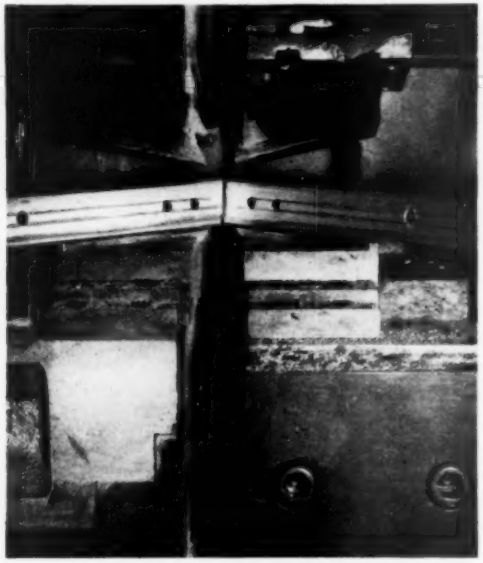


Fig. 7 Close-up of dies for miter welding just before dies close

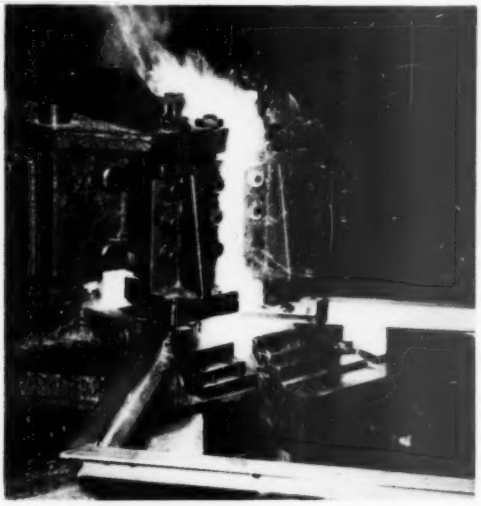


Fig. 9 Flashing cycle

Fig. 10 Miter welder adjustments and controls

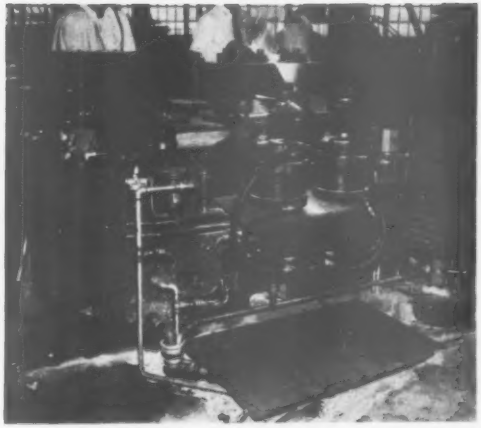


Fig. 11 Rear-view miter welder. The two big air cylinders operate dies clamping the work

In Fig. 6, *A* is stationary electrode clamp; *B*, moveable electrode clamp; *C*, connecting rod to eccentric *D* on shaft *E* which is rotated by the air cylinder *H* through the crank *F*. Motion is controlled by oil cylinder *G* and metering valve which can be adjusted for desired oil flow.

Operation is simple. When work is placed in the dies, operator steps on one foot pedal, closing stationary die. Work is positioned in dies by means of pins. Parts have been cut to exact length and 45° angle required for the 90° miter joint. Operator closes moveable die by stepping on another foot pedal. As die closes, it actuates the control valve letting air into the air cylinder at about 100 psi. When work is clamped, flashing current is applied.

Air cylinder moves crank *F* to right, causing eccentric to rotate in clockwise direction, moving *B* to left, thus closing dies. Meantime welding current has been applied and flashing occurs at rate controlled by metering valve on *G*. This is the flashing period.

The fast pushup cycle is started by the cam *K* which rotates with *E* to a point where the cam rise *J* operates bypass valve *L* which acts to cut off completely the retarding action of the oil cylinder, allowing the pressure in the air cylinder to bang home the moveable die. Control *L* also cuts off the welding current just as the pushup is made.

Pushup is so fast, it sounds like a hammer blow. Maximum force available is 20,000 lb. This is sufficient to squeeze out most of the molten metal from the joint. Die clamping members pinch off flash to produce joints shown in Figs. 3 and 4. System is subject to precise control since all operating members are calibrated.

ECONOMIC SIGNIFICANCE

The two advanced techniques described above are extremely important developments for the entire metalworking industry and for users of aluminum particularly, because they mean aluminum can be used for many new applications where it heretofore was impractical or too costly to fabricate.

With aluminum our second most widely used metal, the importance of expanding the field of use of aluminum cannot be underestimated in terms of what it can mean to the resistance welding industry.

Every resistance-welding machine is sooner or later going to be called upon to work aluminum. It should be possible for the engineer with a little imagination and foresight to greatly improve his welding operations by utilizing the design principles and welding techniques explained above.

In addition to the two methods described for obtaining instantaneous or hammer blow type pushups, there are other methods for obtaining the same result. Not all of them, however, are subject to the same precise control as those described and since exact control of all factors in the operation are so vital to consistent results, the same benefits may not be obtainable.

Take the single feature of flash removal. That alone can mean the difference between getting a job down to a practical cost basis in aluminum, or having to use some other material or fabricating method. Not all welding machines may be able to control the pushup the sufficient speed and force to get the desired result without modifying the equipment somewhat. It is urgently recommended that direct comparison be made between results obtainable with present equipment in the plant and results possible with newest improved flash welders such as those described above. It may often be found that a single job will pay for a new improved type welding machine.

If new machines cannot be obtained due to limited budget or time element, it is quite possible in most cases to modify standard machines to obtain some of the advantages detailed above.

Power Supply for Automatic Resistance Welders

Relationship between power supply and machine design in multiple transformer automatic resistance welders. With proper design, peak demand may be reduced while at same time assuring adequate power supply essential for consistant weld quality.

by T. F. Ellis

INTRODUCTION

DURING the past few years the use of a.-c. resistance-welding machines designed to make a multiplicity of spot welds simultaneously has expanded rapidly, particularly in the automobile industry. The economies effected by being able to weld a complete unit assembly in one operation has created a demand for larger and more complex welders each year.

This increase in size from machines capable of making a few welds to those making several hundred has greatly increased the problem of providing an adequate power supply. The majority of these multiple transformer welders have a relatively low duty cycle in comparison with other types of resistance welders. However, the instantaneous power demand is often of such magnitude that the average plant power system cannot handle this intermittent, low power factor load. In some cases the power company system may also prove to be inadequate.

Production requirements demand a specific operating speed range and consistent weld quality, with a minimum of rejected parts, from each welder. In many cases, certain features may be incorporated in the machine design, without interfering with production requirements, that will reduce the demand on the power-supply system. In other cases, certain features may be incorporated in the supply system design that will insure the adequate power supply essential for consistent weld quality.

Close cooperation between the welder manufacturer, the plant welding engineer and the power company engineer before the welder is installed would enable them to coordinate engineering data and select the most economical and efficient design for the welder and the power supply.

T. F. Ellis is an Electrical Engineer, Kaiser-Frazer Corp., Willow Run, Mich.

This paper was presented at the A.I.E.E. and Affiliate Council meeting of Apr. 28, 1949.

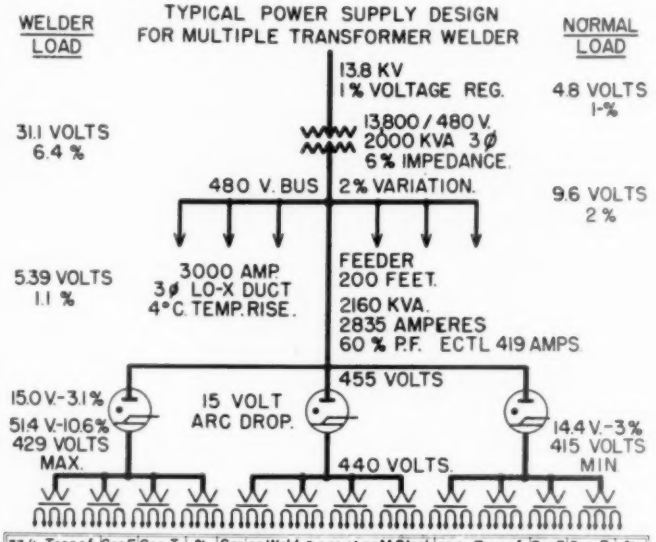
DESIGNING THE POWER SUPPLY

To illustrate the problems involved in the design of an adequate power supply system for multiple transformer welders, the one line diagram in Fig. 1 can be used as an example. All protective devices have been omitted for simplicity.

The welder is designed to weld together several 14-gage mild steel members into a complete assembly. A total of 72 spot welds are to be made simultaneously after a single machine loading operation Maximum production rate to be 120 assemblies per hour.

A total of 12 fixed turns ratio transformers are used (73 to 1) with a 440-v. primary and three 6-v. secondaries per transformer. The single-phase transformers are connected four per phase through three ignitron contactors and fired simultaneously by electronic timers.

The welding engineer has determined that the weld current required to weld two pieces of 14-gage mild steel will be 10,000 amp. with a 40-cycle weld time. The average impedance of the transformer secondary loops, including the workpieces



73/1 Transf.	Sec.E	Sec. I.	% Drop
Rated.	6.00	10,000	-
Voltage Drop.	5.85	9,750	2.5
V.Drop ₵ Var.	5.66	9,430	5.7

Table 1.

Series Weld 2 pcs. 14 ga. M. Steel.
Sec. 10,000 A., 6V., .000600 Ω.
120 Operations/hr 40 ~ Weld
Duty Cycle 22% 72 Spots.
Demand, 180 Kva per Transf.

69/1 Transf.	Sec.E	Sec. I.	% Drop
Rated.	6.40	10,666	-
Voltage Drop	6.24	10,400	2.5
V.Drop ₵ Var.	6.03	10,060	5.7

Table 2.

Figure 1

being welded is found to be 600 micro-ohms.

Now that the above data have been assembled, the power requirement of this welder can be calculated. The instantaneous kva. demand will be 60 kva. (6 v. × 10,000 amp.) per secondary, three secondaries per transformer and 12 transformers or a total of 2160 kva. The transformer nameplate kva. rating should be ignored in these calculations. With the transformers connected as a balanced three-phase load the current demand will be 2835 amp. The duty cycle of operation will be 2.2% (40 cycles per weld, times one weld per operation, times 120 operations per hour, divided by 216,000 cycles per hour). The equivalent continuous thermal load will therefore be 419 amp. (Current demand times the square root of the duty cycle.) The load power factor is estimated to be 60%.

The electrical engineer is now confronted with the problem of designing a supply system capable of handling an instantaneous load of 2835 amp. and a thermal load of 419 amp. In order to have 6 v. available at the transformer secondaries, a primary voltage of 440 v. will have to be maintained, which means that the voltage at the machine terminals under load will have to be 455 v., allowing 15-v. arc drop through the ignitron tubes.

The welder is to be located 200 ft. from the nearest power supply distribution bus. The supply transformer is a 2000 kva., three phase, 13,800 v. primary and 480 v. secondary with an impedance of 6.0%. The substation bus has several feeders supplying power to other plant loads. However, the feeder to this welder will be required to carry only the welding load of this machine.

The first problem is the anticipated voltage regulation on the primary 13,800-v. supply lines. A consultation with the power company engineer has disclosed that the voltage regulation will be maintained within 1% under normal plant load including the load of this welder.

The second problem is the capacity of and voltage drop through the supply transformer. Calculations indicate that the equivalent continuous thermal load of the welder when added to the normal load on the substation bus will not exceed the thermal capacity of the transformer. The voltage drop through the transformer when the welding load is applied will be 6.4% or 31.1 v. (demand times impedance divided by transformer rating).

The third problem is the anticipated voltage variation on the substation bus under normal load conditions exclusive of the load to be applied by the welder. This figure can readily be obtained from a recording voltmeter connected to the bus and in this case is found to not exceed 2%.

The final problem is the feeder from the substation bus to the machine terminals. Considering voltage drop only, the substation bus voltage during weld will be 448.9 v. which is already below the previously calculated minimum required machine terminal voltage of 455 v. leaving no allowance for feeder voltage drop, however it may still be possible to operate this welder within required weld quality tolerances.

The use of cable for the feeder is not practical in this case, but low-reactance bus duct does offer a possible solution. Three-phase, 3000-amp. duct has a voltage drop of 0.0000095 v. per ampere per foot at 60% power factor. The total voltage drop for this feeder would then be 5.39 v. or 1.1%.

The resultant voltage drop caused by the actual operation of this welder will therefore be the sum of the drop through the supply transformer (31.1 v.), the drop through the feeder (5.39 v.) and the drop through the ignitron tubes (15 v.) a total of 51.4 v. or 10.6%.

In addition to the voltage drop, the voltage variation must be considered. The magnitude of this variation was previously determined to be 1% in the primary supply and 2% on the substation distribution bus. Adding this 3% to the 10.6% voltage drop results in a possible total voltage drop of 13.6% or a minimum welding transformer primary voltage of 415 v. and a maximum of 429 v., a variation of 14 v. or 3%.

According to many authorities a 10% voltage drop is acceptable under normal conditions with all other factors remaining constant. Under certain conditions this may be true, however, it is rather misleading and requires additional information for clarification. Voltage drop, if expressed as a percentage of the steady state or average voltage on the substation bus, may be of any value within practical limitations depending upon the relationship between the available voltage on the distribution bus and the required voltage at the welding transformer primary terminals. This figure remains relatively stable, occurring only during the actual weld operation, and can be compensated for in the design of the welder and/or power supply.

On the other hand, voltage variation is due to intermittently applied loads other than that of the welder itself and is therefore not a stable factor. Consistent weld quality requires that the weld current be maintained within acceptable tolerances. In a correctly designed transformer the current and voltage are essentially linear so uniform weld quality depends upon maintaining the voltage at the primary terminals within acceptable voltage variation tolerances.

It is apparent that any voltage drop or voltage variation at the welding transformer primary should be expressed as a percentage of the required voltage at that point in the circuit rather than as a percentage of the supply voltage at the substation bus. In an ideal system the welder and power supply can be designed to compensate for voltage drop so that the voltage at the welding transformer is of the desired value. Weld quality then becomes only a function of voltage variation.

Referring again to Fig. 1, the voltage drop of 10.6% resulted in a voltage at the welding transformer of 429 v. This is 11 v. or 2.5% under the minimum 440 v. requirement and is the only portion of the over-all voltage drop that will affect the secondary circuit and the weld quality. If the maximum 3% voltage variation occurred during weld, the voltage at the transformer would be 415 v. or 5.7% below minimum requirements. Table 1 indicates the respective transformer secondary current and voltage values under these conditions. The maximum current obtainable would be 9750 amp. and the minimum 9430 amp. or 5.7% under the estimated welding requirement.

From the foregoing calculations, it can be concluded that by installing a 3000-amp. low-reactance bus duct as a feeder, the weld current of this welder could be held between 2.5 and 5.7% of the required magnitude. Under normal operating conditions good quality welds would be obtained. However, the maximum recommended weld current (or voltage) tolerance for this type of welder should not exceed 5%. A greater voltage variation could be tolerated providing all other variables remained constant but in actual production this ideal condition is never attained, at least for any appreciable length of time.

DESIGNING THE WELDER

In the example just illustrated it was necessary to install a relatively costly bus duct feeder to supply adequate power to a single welding machine. If the welder manufacturer had been adequately supplied with complete engineering data on the existing or proposed power-supply system and the acceptable production tolerances, it is possible that he could have designed the welder to improve the weld current tolerance and/or eliminated the necessity for such a large and costly feeder.

For example, if the estimated voltage drop and voltage variation data had been furnished along with the required weld current, transformers with a 69 to 1 turns ratio could have been installed. Table 2 indicates the respective secondary current and voltage values that would have resulted from this change in design. It will be noted that the desired 10,000-amp. welding current is available with the maximum 5.7% voltage drop and the current variation from the desired value is only 3.2%. It is desirable to have this condition with fixed ratio transformers to provide a small safety factor for minor voltage drops in connections, machine wiring, etc.

Another method of accomplishing the same result with the additional advantage of greater flexibility would be through the use of tapped transformers. Emphasis must again be placed on the necessity of the welder manufacturer being in possession of complete power supply and production requirement data. Tapped transformers are of absolutely no value if they are not able to correct for applied primary voltages above or below their normal rating. This, of course, is with reference only to voltage drop or excessive voltage, as voltage variation will not be affected by the design of the transformer.

The weld current tolerance of this machine could have been improved by using either of the above methods in the original design, however the 3000-amp. bus duct feeder would still be necessary to provide an adequate power supply. Figure 2 illustrates one design change that could have been made in the welder to reduce the size and cost of the feeder as well as the demand on the entire power-supply system.

In the first illustration, all 12 transformers were fired simultaneously, four per phase, using three ignitron contactors. By installing three additional contactors and timers the weld operation can be made in two stages. In other words, six transformers would be fired simultaneously, two per phase, followed immediately by the remaining six, two per phase, thereby retaining a balanced three-phase load. The instantaneous demand would be reduced to 1080 kva. or one-half the original value, the duty cycle would be increased to 4.3% from 2.2% and the maximum number of operations reduced from 120 to 117 per hour.

This 2.5% reduction in production rate must be taken into consideration because it might not be acceptable to the user and would require additional machine design changes.

If these reduced demand figures are applied to the same power-supply system as used in the first illustration, the voltage drop through the power-supply transformer would be reduced to 15.5 v. or 3.2%. Assume the primary supply voltage regulation and the distribution bus voltage variation remain the same as previously calculated.

The 3000-amp. bus duct feeder could now be replaced with 1000-amp. low-reactance duct, resulting in a voltage drop of 7.23 v. or 1.5%. The total drop under load would be 37.7 v. or 7.8%. The minimum welding transformer primary voltage would be 428 v. and the maximum 442 v. Table 3 indicates the resultant transformer secondary current and voltage values.

Furthermore, by the installation of welding transformers having a 68 to 1 turns ratio, a 750-MCM cable feeder could be installed with the results indicated in Table 4. Here again, it will be noted that the desired welding current

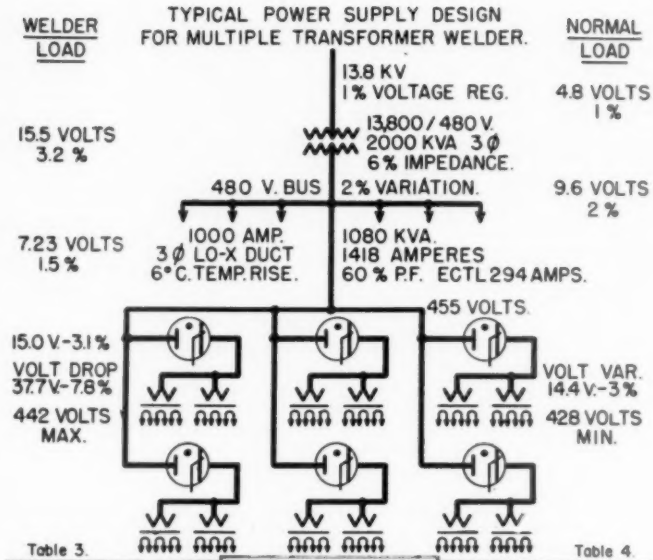


Table 3.

73/1 Transf.	Sec.E	Sec.I.	% Drop
Rated.	6.00	10,000	–
Voltage Drop.	6.03	10,050	–
V.Drop & Var.	5.84	9,733	2.7

Series Weld 2 pcs 14 ga M Steel
2 groups/6 Triple Sec., conn 4/ph
Sec. 10,000 A., 6V., .000600 Ω.
117 Operations/hr. 40 w Weld.
Duty Cycle 4.3% 72 Spots.
Demand, 180 Kva. per Transf.

Table 4.

68/1 Transf.	Sec.E	Sec.I.	% Drop
Rated.	6.47	10,783	–
Voltage Drop.	6.24	10,400	3.6
V.Drop & Var.	6.03	10,050	6.8

Figure 2

of 10,000 amp. is available with a variation tolerance of only 3.2% although the maximum voltage drop is 6.8% of the rated transformer primary voltage. Also tapped transformers could be used here effectively if adequate data is made available to the welder manufacturer prior to actual machine design.

One important fact to remember when decreasing transformer turns ratios to correct for feeder voltage drop is the thermal capacity of the feeder. In the preceding example, 500-MCM cable is the minimum that could be used with the equivalent continuous thermal load of 294 amp.

DESIGN SELECTION

The foregoing illustrations have presented several methods of coordinating welder and power-supply designing to assure an adequate supply of power to a large multiple transformer welder within permissible weld quality tolerances. The examples were based primarily on the relationship between feeder and machine design. In some cases, an increase in the capacity of the primary supply lines and/or the supply transformer could be avoided by a change in the proposed design of the welder. In other cases, correct design of the welder and the power-supply system could reduce or prevent trouble with other electrical equipment supplied from the same source. This is especially true with respect to light flicker, which occasionally becomes a very serious problem in resistance welding.

The first consideration in selecting a particular design for the welder and/or the power-supply system is usually the relative costs involved. In order to arrive at a practical solution to this problem, the following factors must be considered:

1. Permissible weld quality tolerance-cost of rejects due to unsatisfactory welds.
2. Cost of increasing the capacity of power company supply system if demand is excessive or poor voltage regulation interferes with other users.
3. Cost of installing a power-supply transformer of adequate capacity or the replacement of an existing unit with one of larger capacity or lower impedance.
4. Cost of installing an adequate distribution system or increasing the capacity of an existing system.
5. Cost of installating specially designed welding transformers or additional contactors and timers on the welder.
6. Cost of installing protective devices of adequate interrupting capacity.

7. Power cost, if special rates are involved.
8. Maintenance costs and the cost of production losses in the event of a breakdown involving any other portion of the system.

All of the above factors must be considered plus the additional cost of any special installation, construction or production problems present in a specific application. Consideration must be given to each factor separately and also as a completely integrated, economical and adequate multiple welding system.

CONCLUSION

The following is a recapitulation of the design data that should be compiled by the welding or electrical engineer, power company engineer and the welder manufacturer before a multiple transformer welder is installed:

1. Permissible weld quality tolerance.
2. Welding current required.
3. Welding transformer secondary loop impedance.
4. Instaneous kva. demand.
5. Duty cycle with permissible variation tolerance.
6. Load power factor.
7. Primary power supply voltage regulation.
8. Distribution bus-voltage variation.
9. Voltage drop at welding transformer primary terminals.
10. Voltage variation at welding transformer primary terminals.

This list includes only the factors primarily essential to the design of an adequate power supply system. The design of the welder itself has a direct relationship to the power supply system and all of this data must be available to the welder manufacturer.

There are, of course, many other variable factors that enter into the problem of obtaining satisfactory welds with these multiple transformer welders. However, the effect of these other variables upon obtaining uniform weld quality is greatly reduced if an adequate power supply is provided, capable of maintaining the weld current within specified tolerances.

CURRENT WELDING LITERATURE

Accident Prevention. How to Interrupt Control Circuits Safely, C. B. Stadum. Welding Engr., vol. 34, no. 5 (May 1949), pp. 34–35.

Agricultural Machinery, Welding. Farm Equipment Manufacturing Methods and Costs Improved by Resistance Welding. Steel, vol. 125, no. 7 (Aug. 15, 1949), pp. 97–100, no. 8 (Aug. 22), pp. 64–67.

Agricultural Machinery. Welding on Farm, P. Glanzer. Welding Engr., vol. 34, no 5 (May 1949), pp. 32–33.

Airplane Manufacture, Welding. Here's How Welding Research and Development Pay Off at Glenn L. Martin Co., L. Barrett and F. Chitty. Industry & Welding, vol. 22, no. 5 (May 1949), pp. 48–50, 52, 55, 76–79.

Airplane Manufacture. Welding in Aircraft Construction, G. B. Evans. Aircraft Production, vol. 11, no. 128 (June 1949), pp. 200–204.

Aluminum Alloys, Testing. Consideration of Nature of Brittleness at Temperatures Above Solidus in Castings and Welds in Aluminum Alloys, W. I. Pumphrey and P. H. Jennings. Inst Metals—J. vol. 75, pt. 4 (Dec. 1948), pp. 235–256, 2 supp. plates.

Automobile Manufacture, Welding. Modern Welding Procedures in Building Motor Car Bodies, E. O. Courtemanche. Machine & Tool Blue Book, vol. 45, no. 5 (May 1949), pp. 121–122, 126–132.

Automobile Manufacture. Welding Applications in Automotive Construction, J. F. Randall. Soc. Automotive Engrs.—J., vol. 57, no. 6 (June 1949), pp. 25–27.

Barges, Welded Steel. Prefabricated Construction of Welded-Steel Barges. Engineering, vol. 168, no. 4357 (July 29, 1949), pp. 104–105 (illus.), 108; see also Engineer, vol. 188, no. 4878 (July 22, 1949), pp. 101–102.

Barges, Welded Steel. Mass Production of All-Welded Barges. Shipbldg. & Shipg. Rec., vol. 74, no. 3 (July 21, 1949), p. 75 (illus.), 76–77.

Brazing Silver Alloy. Induction Brazing with Silver Alloys, F. W. Curtis. Steel, vol. 125, no. 3 (July 18, 1949), pp 82–84, 124–126.

Car Building. British Welded Railway Cars, F. Brewster. Welding Engr., vol. 34, no. 6 (June 1949), p. 29.

Cast Iron. "Hot Welding" Steam Cylinders in Germany, J. J. Christie. Welding Engr., vol. 34, no. 5 (May 1949), p. 39.

Dairy Equipment, Manufacture. Gas-Shielded Arc Welds, Stainless Cups, C. Root. Am. Mach., vol. 93, no. 13 (June 30, 1949), pp. 94–95.

Electric Welding, Arc. Contact Arc Welding. Australasian Engr. (Feb. 1949), pp. 69–71.

Electric Welding, Arc, Inert Gas. Argonare Welding Process. Mech. World, vol. 125, no. 3257 (June 17, 1949), pp. 701–702.

Electric Welding, Arc, Sheet Metal. "Welding-through" Joins Sheet Metal, H. E. Cable. Welding Engr., vol. 34, no. 5 (May 1949), pp. 30–31.

Electric Welding Machines, Maintenance and Repair. New Maintenance System Trims Welder Downtime 80 Per Cent, W. J. Scanlon. Factory Mgmt. & Maintenance, vol. 107, no. 5 (May 1949), pp. 106–108.

Electric Welding Machines, Resistance. World's Largest Pipe Welder, C. B. Clason. Welding Engr., vol. 34, no. 5 (May 1949), pp. 42, 44.

Electric Welding. Resistance Welding in Modern Industry, H. S. Narayana Rao. Instn. Engrs., India—J., vol. 29, no. 3 (Mar. 1949), pp. 83–95.

Electric Welding. Resistance Welding. Automobile Engr., vol. 39, no. 515 (June 1949), pp. 223–230.

Excavating Machinery, Manufacture. Big Scoop . . . (Welded, of Course). Industry & Welding, vol. 22, no. 7 (July 1949), pp. 26–29, 74–76.

Gas Welding Torches. Flame Spectrum of Acetylene from 1 to 5 Microns, E. K. Plyler and C. J. Humphreys. U. S. Bur. Standards—J. Research, vol. 42, no. 6 (June 1949) (RPI 993), pp. 567–572.

Heating, District, Hospitals. District Heating of Perth Hospital, Australia, H. B. Fletcher. Air Treatment Engr., vol. 12, no. 6 (June 1949), pp. 154–156.

Magnets, Permanent. Induction Brazing Methods Applied to Permanent Magnets, D. Hadfield. Metallurgia, vol. 40, no. 237 (July 1949), pp. 165–166.

Materials Testing, Non Destructive. Report of Committee E-7 on Non-Destructive Testing. Am. Soc. Testing Matls.—Preprint, no. 76 for meeting June 27 (July 1, 1949), 4 pp.

Metals, Hard Facing. Tips on Hardsurfacing, M. Riddibough. Industry & Welding, vol. 22, no. 5 (May 1949), pp. 34–35, 37–38.

(Continued on page 1124)

PRACTICAL WELDER AND DESIGNER

Controlled Distortion—An Aid to Metal Working

by Joe L. Morris

ANY welder who understands the rudiments of his trade is acutely aware of the changes in shapes that follow welding of structural members. Usually the welding operator uses all the devices at his disposal to minimize the distorting effects of heat induction into the workpieces.

In general, welding sequence schedules are formulated for the express purpose of reducing distortion or for limiting stresses to reasonable values. So thoroughly have the principles of distortion been indoctrinated that a welder seldom thinks of the tremendous forces causing curvature, buckling, warping and the like as ever being identified with any of his more valuable welding techniques.

It is the purpose of this paper to show several of the many ways in which distortion, resulting from controlled heat applications, may be of inestimable value to the welding operator.

In its simplest form, what induces metal to change shape when welded or otherwise heated? Consider a flat bar as in Fig. 1 which is, for example, $^1/_4$ x 2 x 24 in. in size. Should a spot be quickly heated to a bright cherry red at *A*, the area heated becomes significant in several different ways. It becomes soft and plastic, thus losing its strength; it tends to grow in all directions but its growth is restricted in all directions save that of thickness. Obviously then, the additional volume induced by heating can only be accommodated in the one, unrestricted direction; the bar becomes thicker in the heated area.

After heat is withdrawn and the temperature of the spot starts dropping, the cooling metal tends to contract in a normal manner. Keep in mind, however, that the cooling metal is rigidly confined by surrounding cool metal which strongly resists the contraction forces set up. With continued fall in temperature the heated metal gradually regains its strength and since its rigidity is also increasing the decrease in volume cannot be altogether made up from the thickness direction, therefore a state of stress is set up in the bar. The cooling spot tends to pull in all the other directions. Little distortion, so far as the straightness of the bar is concerned, will come from this treatment since the area chosen was near the neutral axis.

Control measures may now be imposed. Control means nothing more than properly choosing the location of spots to give the required distortion.

Consider another bar of similar dimensions (Fig. 2) but in this case heat at *B*. It is evident that the confinement of the spot will not be as complete as in Fig. 1, but it is further evident that the deformation will be appreciable since the area treated is removed from the neutral axis of the bar. The exaggerated effect is shown in Fig. 3. It is reasonable to expect that a series of areas along the bar edge similarly treated would greatly multiply the effect.

The principle explained may be applied in various ways. By this method long members may be straightened, buckles removed from sheet metal, bands shrunk, holes decreased in diameter and seized studs loosened and removed.

Heat induction is not limited to any one method. The choice of heating apparatus will depend entirely on what is needed to be done. Spot heating using the oxyactylene torch is a common method. Where a great amount of deformation is required and where there is no objection to the addition of metal, the metal are is frequently used.

JOB I

A centrifugal pump shaft, for example, has been sprung and it is desired that it be straightened. This job is best done by mounting between centers on a lathe.

As the shaft is slowly turned by hand, the location, direction and extent of the deformation can be noted. Straightening may be effectively done in the following steps:

1. Quickly heat, to a bright cherry red, a spot on the side opposite to the direction in which the shaft is to be shifted (Fig. 4). For a 2- or 3-in. diameter shaft the heated spot should be about equal to the size of a 25¢ coin; the

J. L. Morris is Asst. Professor at Georgia Tech.

Fig. 1 Little distortion is obtained by spot-heating near neutral axis

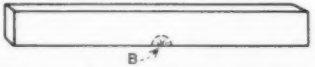


Fig. 2 Spot-heating away from neutral axis of member is usually most effective

Fig. 3 Result of spot-heating some distance away from neutral axis to obtain distortion

Fig. 4 An exaggerated bend in a shaft that may be straightened by spot heating

Fig. 6 The propellar shaft of a popular make automobile

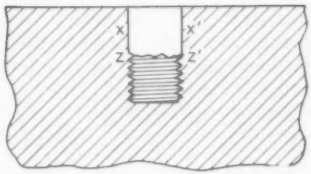


Fig. 8 A broken subsurface stud

areas may be larger or smaller as the shaft diameter is larger or smaller, respectively. This type of straightening is best done with an oxyacetylene torch which is equipped with a No. 10 welding tip (the tip size will vary with the section heated).

2. Cooling of the spot may be done by allowing the heat to be dissipated through natural channels, however the most common practice is to cool with water.
3. After cooling is complete, recheck for straightness by using a dial test indicator. This reading as compared to the initial reading will give an approximate idea as to how much deformation can be obtained from each spot heat.
4. If more straightening is required, repeat the operation. It is advisable to locate the new spot at least 2 in. along the shaft from the first one.
5. Should the deformation exceed the amount required, a correction may be made by spot heating the shaft diametrically opposite the original treatment.

It is important to mention that some steels will harden appreciably when spot-heated and cooled for straightening. In case there is a question regarding the hardening properties of the steel, a simple, harmless test is to spot heat and cool the end of the shaft. If the spot becomes file-hard the described straightening procedure is not recommended.

JOB II

In erecting gate guides (spillway), from heavy H sections to be set to close tolerances, turnbuckles and jackbolts are usually used for aligning and securing (Fig. 5). If a stress is to be applied at a point to obtain the last several thousandths of an inch to meet the tolerance requirements, frequently difficulty is encountered with turnbuckles because of the magnitude of the stress involved.

The welder's method to obtain this high state of stress is to use the handiest piece of reinforcement steel scrap of adequate size to take the place of the turnbuckle, weld this securely in place, allow to cool and take measurements. Add to the deformation by running short, small beads on the bar in the longitudinal direction. To control the amount of shrinkage the operator only has to observe the extent of the movement for a unit length of bead. If too much strain is obtained from this procedure an opposite effect can be obtained by peening the bar.

In the above-described method it is important that the welder does not become impatient and made the weld deposit too large. To do so would cause excessive temperature rise and the bar would lose its tensile value and plastic flow would ensue. Make all measurements when the bar is cold.

JOB III

In a certain popular automobile the propeller shaft is of the open type and made from seamless tubing The needle bearings in the universal joints fit over hardened and ground pins which are pressed through the ends of the propeller shaft as in Fig. 6. These pins which are normally a press fit, either become loosened in the service or were improperly fitted by the manufacturer.

A request was made by the writer in several large repair shops to restore a shaft of this type to service by shrinking the hole through which one of the pins

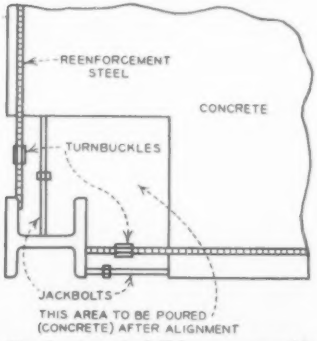


Fig. 5 A vertical H beam gate guide

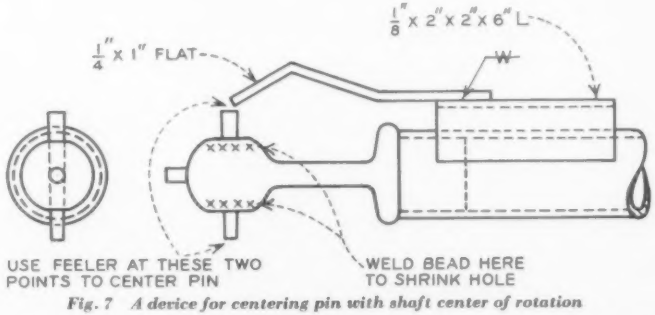


Fig. 7 A device for centering pin with shaft center of rotation

was fitted. In every instance this repair was refused on the grounds that the method was impracticable. It was recommended that the entire shaft be replaced at a cost of $36 plus labor.

This job may be done in 1 hr. by a welder as follows:

1. Remove propeller shaft from car.
2. Disassemble joint.
3. Run a small weld bead around hole with the arc welder to shrink.
4. Ream hole if necessary, press in pin and reassemble joint.
5. Replace shaft in car.

When pressing in, the pin must be located in such a position that the tube will rotate perfectly about its longitudinal axis. The location of the pin will determine the axis of rotation, therefore the welder will have to make up a gage as shown in Fig. 7. The use of the gage for locating the pin in relation to the axis of rotation is indicated.

JOB IV

Removing broken and seized studs is a job frequently more profitable than run-of-mill welding. Those stubborn, rusted-in, below-the-surface type are the most appropriate for the welder.

Two conditions must be met in removing the more difficult stud. First, its temperature must be quickly increased without appreciably increasing that of the surrounding metal. This causes plastic flow or deformation in the heated stud and on cooling it will have a decreased diameter. Secondly, an attachment must be made to the stud to facilitate removing. Do not be hasty about screwing out the stud after welding on the attachment. The procedure used will prove more successful if the welded part is allowed to completely cool. If water is used to speed the job it is important that the surrounding metal be reduced in temperature first and the stud afterward. This order of cooling will obtain greater plastic flow in the broken stud, hence greater loosening effect.

Figure 8 shows a below-the-surface stud that ordinarily is a problem with the usual methods of removal, especially if it has been hardened. Truck wheel hubs are typical of these jobs. The hole and stud are machined and fitted body-tight at x–x'. In service, if allowed to run loosened, the latter will fail at z–z'. If these are hardened studs, the usual drill and extractor method will not apply.

The most effective procedure ever used by the writer is to line the smooth part of the hole above the stud with a snug-fitting piece of sheet copper or copper tubing of the correct size (Fig. 9).

The welder will fill the hole using a high current setting on his machine and preferably an E6010 electrode. The smaller sizes of electrode should be chosen.

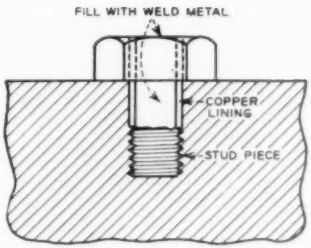


Fig. 9 Weld on a nut to facilitate removal of stud

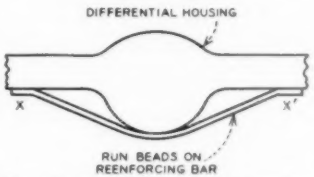


Fig. 10 The differential housing may be prestressed by running beads on the reinforcing bar

Direct all possible heat into the stud when first starting to weld to obtain greatest possible penetration and loosening effect. The copper will fuse with the weld deposit, but in so doing will prevent the weld metal from adhering to the surrounding metal. Do not stop welding until the hole is completely filled, particularly in sizes $^7/_8$ in. diameter or less. Slag accumulation in the hole will be no problem if a gaseous electrode is used. The final step of welding is to attach a piece of scrap or a nut for the purpose of backing the stud out.

At this point some degree of judgment is required. With complete cooling a wrench may be applied but use an oscillatory motion until the stud turns freely. Penetrating oil will prove useful in this step.

If the first attempt does not extract the broken piece try again. A second attempt will usually turn the trick. The secret is in applying the heat and cooling to obtain maximum deformation.

JOB V

In attaching a supporting member onto a truck differential housing as in Fig. 10, the owner desired that considerable stress be left to remain in the tensile reinforcing bar.

This was accomplished by welding the bar to the housing in the usual manner at x and x', after which longitudinal beads were deposited on the bar surfaces at any convenient place. Beads deposited against the bar in this manner set up a state of high-tensile stress in the bar.

The idea in this procedure was to prestress the housing to offset service load deformation.

Cam Plates, Pallets & Wedges

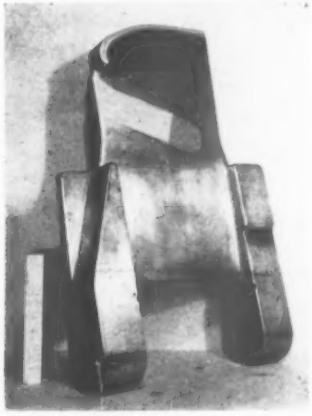
CAM PLATES

THERE are eight to ten different types of these cam plates developed by Naval Ordnance of the approximate dimensions shown in the adjacent photograph. They are used on 5-in. 38-caliber mounts.

Between 8000 and 9000 of these various sizes of cams were overlaid with Grade V of the 46E7 Specification.

The cams are made of a medium carbon steel. The cam illustrated is the mount on which Ampco-Trode 250* was used for an overlay surface. This particular cam is a part of the breech mechanism for the opening of the breech-block after firing. The hardened steel roller follower follows from the upper tip of the overlaid surface down the curved edge and with sideward movement of the cam, the roller then travels over the curved portion at the top right and then down the heavy shaded area toward the middle of the cam. The overlay on the path of the cam must be absolutely sound. One out of ten are spot checked by x-raying to make sure that the surface is sound.

* A.W.S.-A.S.T.M. Specification E CuAl-D.



Overlaid Cam Plate

Coated Aluminum Bronze Electrode

In applying Ampco-Trode 250, $^{5}/_{32}$ and $^{3}/_{16}$-in. diameter electrodes were used and two layers built up on the cam surface and out over the edges of the cam. This surface was then machined down leaving $^{1}/_{8}$-in. overlay for the cam to travel over.

This was one of the first coated aluminum bronze electrode applications in ordnance and was approved and extensively used after many cycles of test operations had been completed.

Overlaid cam plate

PALLETS

On the 5-in., 25 caliber mount, there are two small pallets on each side of the breech-block of the relative size as shown in the photo below, which have a $^{1}/_{8}$-in. finish as shown, of Ampco-Trode 300† (Grade V, 46E7 Specification). These pallets are inserts on the breech-block, made of material to meet the aluminum bronze specification 46-B-17.

Hard Bronze for Contact Surface

The coated aluminum bronze electrode overlaid surface is the contact surface for the extractor lug, which actuates the extractor in removing the cartridge case from the gun. These pallets are illustrated, center of the lower photo, with the coated aluminum bronze electrode overlay specified.

† A.W.S.-A.S.T.M. Specification E CuAL-E.

U. S. Navy Official Photo

WEDGES

These parts, of the type shown in the photograph below, were originally of hardened steel but due to galling on the breech block, coated aluminum bronze electrode overlay was made on the beveled and top surface and then finally on the circumference of the larger diameter.

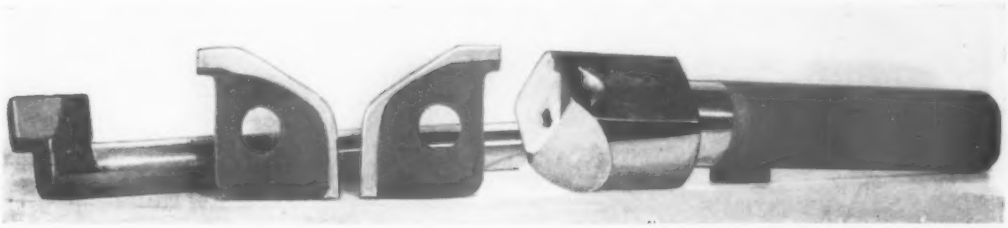
Different Hardness Used

Originally the overlay was coated aluminum bronze electrode (Grade V of 46E7 Specification) for the entire surface overlaid. This was later changed to have coated aluminum bronze electrode only on the tapered and end surface and a general-purpose, coated aluminum bronze electrode was used on the circumference of the larger diameter. This was used on the 6-in., 47 caliber breech mechanism on between 500 to 1000 parts.

Serves Two Purposes

This wedge serves two purposes. It acts as a support to keep the weight of the bolt off of the cam and also acts as a locater for the breech-block of hardened steel. As the breech-block drops the wedge, following a grooved path in the breech-block, it acts as a guide to keep the block centrally located. The cylindrically overlaid surface moves up and down in a guide bushing. The overlay of coated aluminum bronze electrode on this surface prevents galling in the guide.

In making this overlay, the tapered side and the end are overlaid first with coated aluminum bronze electrode deposit and then the cylindrical surface is overlaid with a general-purpose coated aluminum bronze electrode. The overlaid surface is then machined to size.



Pallets and Wedges overlaid with aluminum Bronze

X-Ray Qualities Required

The tapered surface and the end of the coated aluminum bronze electrode overlay must be absolutely sound and these parts are x-rayed for soundness. When the part is finished, the depth of overlay of both grades of coated aluminum bronze electrode is $^1/_8$-in.

Welding Old Iron Castings

by Rene D. Wasserman

EVERY welder who has tried to weld old cast iron knows how difficult these repairs can be. Many of these old castings come from machines and equipment no longer in production. Replacement parts are not available, but there is still a lot of wear left in the equipment—wear that can only be obtained by repairing the broken castings.

Many castings that have been underground or exposed to corrosive chemicals or heat undergo serious changes in metallic structure. The casting surface no longer has sufficient iron content to make a good welding base. Consequently, a welder has extreme difficulty in making his welds bond.

Other castings have become saturated with oil or chemicals. When the surfaces are raised to welding heats, the impurities boil out. This makes it impossible to get a bond or causes the weld to be porous and weak because of the escape of gases through the molten weld metal. Prolonged heating will cook most of these impurities out, but this is expensive and tedious. Furthermore, there is no assurance that the dried surface still will not be difficult to weld.

Here is a new procedure that has been worked out for these old castings. It really does the job. Eutectic Cut Trode, a cutting electrode that was introduced to industry last year for the arc cutting of all metals without oxygen, is the key to the solution. It operates on all currents with a standard electrode holder and welding machine so that there is no need for new cutting equipment.

The cutting electrode replaces the slow chipping or grinding that was formerly used for the beveling preparation. An arc is struck and the welder uses the rod at

Rene D. Wasserman is President of Eutectic Welding Alloys Corp., New York, N. Y.

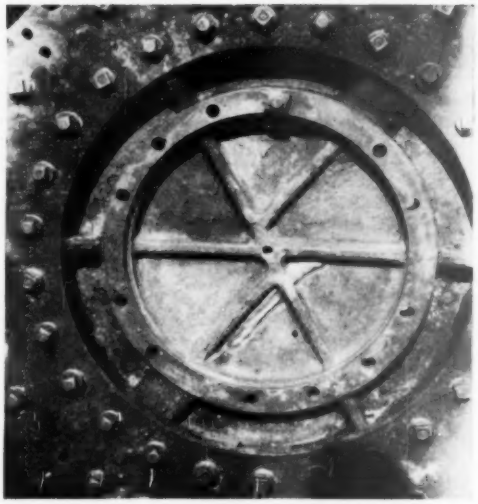


Fig. 2 The head of this linseed oil drier was cracked in service

Ordinary welding alloys would not bond to the oil soaked metal. CutTrode and EutecTrode 24/49 combined to make a perfect repair that put the drier back in immediate service and avoided a stoppage in oil production

Fig. 1 Close-up of a preparation of old corroded cast iron

Note particularly the shiny metallic surface of the gouged area. The excellent bead on the right was made with EutecTrode 24/49. The bead on the left was made with BronzoChrom 185FC, a brazing-type alloy for torch use. Both of these "Eutectic Low-Temperature Welding Alloys" produce perfect bonds through surface alloying without fusing the cast iron

Fig. 3 A broken tooth put this heavy gear out of service in a Pennsylvania coal mine

Note that tooth contour was so well held that only a slight amount of hand grinding was required to complete the repair

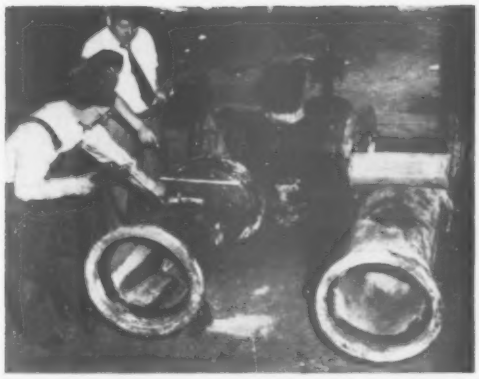


Fig. 4 A high pressure sewer system installation appeared headed for a shutdown because necessary piping could not be obtained

a low angle—directing it into his cut just like a torch. The special coating maintains the proper gap distance and concentrates and intensifies the heat of the arc to produce a clean, narrow cut. This avoids the extensive and damaging heating of carbon-arc cutting and the ragged cuts that are made with the uncontrolled arc of ordinary arc-cutting methods.

As soon as the profile is completed, the arc is played back and forth over the metal surface. The intense heat of the arc thoroughly scours the surface and drys out the oil and other impurities in a matter of seconds. Surface graphite and carbon that always is smeared over a ground or chipped cast-iron surface is burned away. In the course of this final scouring, the beveled surface picks up a considerable amount of steel from the CutTrode, and when the slag is removed, the surface is brightly metallic and shining. This makes a perfect welding base—even better than new cast iron.

Thus in one simple operation, all steps of cleaning and preparing old cast iron for welding are efficiently combined in one simple, time-saving operation. Furthermore, the welders save even more time in continuing these repairs by simply switching to EutecTrode 24/49, a special electrode for "cold"-welding cast iron. All that is needed is a quick readjustment to the recommended settings for the electrode size that is selected.

This is a low-heat electrode which is of unusual value in the welding of cast iron because it avoids the troubles of high-heat fusion welding or ordinary brazing. Cracking, embrittlement, distortion, warping and grain growth are all minimized. There is no fusion or puddling of the base metal—no complicated technique—no slow preheating or postcooling. The welder is able to see what he is doing every second so that he can control his weld perfectly.

The actual welding of these old castings with this electrode is very simple and the welder need follow only a few simple rules. The arc must never be allowed to play on the casting but is carried at all times on the weld metal. The welder uses a short to medium arc and runs beads that are usually less than 2 in. long. Each bead is peened, wire brushed and allowed to cool. The casting must be kept cool and not allowed to show color at any time.

The first bead to seal a crack is narrow and very rapidly run. Each weld should consist of at least two layers of weld metal. The last beads can be made wider but never should they be wider than three times the electrode diameter. The welder must take care in applying additional layers that he does not remelt the previous weld but just melts the surface sufficiently to bond to it.

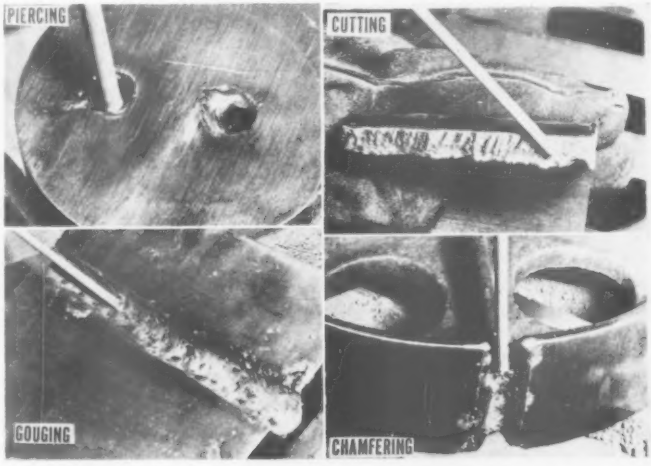


Fig. 5 Four photos showing the way in which CutTrode is used in preparing cast-iron surfaces for welding repairs. The cutting action is quick and easy

The Quickest and Cheapest Way to Make a Box Beam

WHILE the advantages of strength and lightness inherent in the box-beam type of construction are apparent to all, the cost of producing these beams by riveting or other methods of fabrication has frequently been so high as to preclude the use of this type of construction. However, these beams can be made quickly and economically by using "Unionmelt" welding. This process is characterized by its high welding speed and consequent low cost per foot of weld.

The sturdy dipper sticks shown in Fig. 1 were made by Dominion Bridge Co. with a minimum of fabrication costs by using this speedy, high-quality welding process. The beams, 16-ft. long, are made from 12- x 6-in. angles that are $^5/_8$ in. thick. The long leg of each angle was beveled 30° to produce a welding vee for the butt-corner type of joint which was backed by a $^1/_2$-in. diameter rod. After the parts are tacked by manual-arc, three weld passes are applied by the Unionmelt machine.

Another form of box section is made by this company for use as axles of their power shovels. To make these, two channel sections are rolled from 1-in. plate and are welded face to face. The edges are beveled to provide a 22° vee and a strip $^5/_8$ in. thick by $1^1/_2$ in. wide backs the joint. Five passes with the Unionmelt machine fill up the seams and give a slight reinforcement. Not only is Unionmelt welding faster than the manual-arc because of the higher currents used, but there is no need for chipping of the seams between passes. The fused Unionmelt composition strips off by itself and leaves the weld metal smooth and clean, ready for the next pass.

Data and illustrations courtesy of The Linde Air Products Co., New York, N. Y.

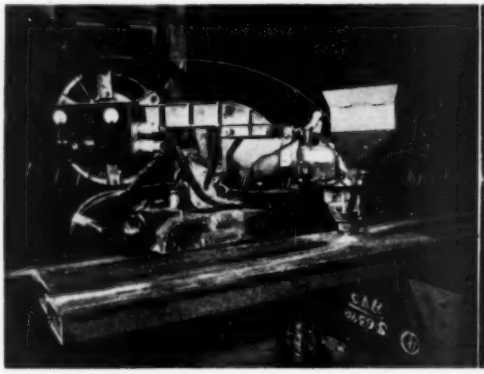


Fig. 1 "Unionmelt" welding 16-ft. dipper sticks at 12 in. per minute

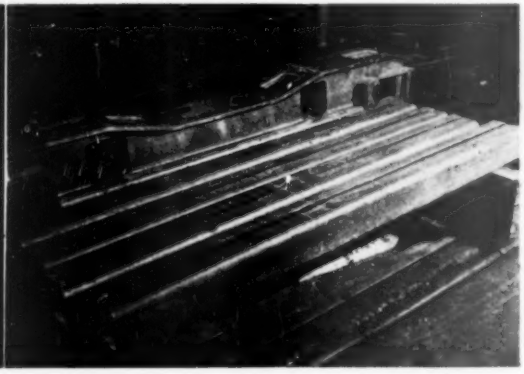


Fig. 2 Box beams, 11 x 12 x 1 in. thick are made by welding two channel sections together

Hard-Facing vs. Wear

by W. C. Owens

INCREASING the life of a shovel, hoe, plow share, cultivator sweep, road grader blade and other earth-moving equipment is important to the owner. Anyone with a welding outfit can protect the wearing edges by covering them with a hard wear-resistant alloy. An ordinary hand shovel or the blade of a road scraper—size makes no difference—that is hard faced will last several times longer than an untreated part.

Hard facing usually is a simple operation. To hard face a shovel, select a small size welding tip, bronze welding flux, and a good hard-facing rod.*

* Instructions are for iron base rods, such as Haynes 92.

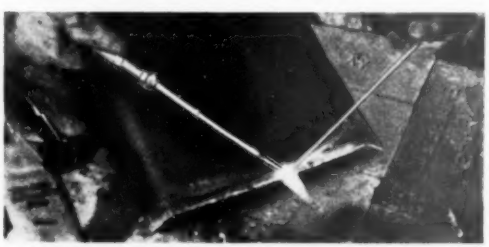


Fig. 1 Heat the shovel only to a dull red when you hard face with Haynes 92 iron base rod

W. C. Owens is Process Service Representative, The Linde Air Products Co., Pittsburgh, Pa.

Clean the back edge of the shovel with a file, a wire brush or a grinding wheel until the metal is bright. Adjust the blowpipe flame to a slight excess of acetylene and heat one corner of the shovel until it turns a dull red. Do not let the shovel sweat or melt.

Bring the end of the welding rod between the flame and the shovel and form a puddle. Deposit rod metal and move the puddle across the shovel. As the metal ahead of the puddle reaches a red heat, the puddle will spread over it. Dip the rod into bronze welding flux often to get a smooth surface. The hard-faced area should be about $^3/_8$ in. wide and $^1/_{32}$ in. thick. Let the shovel cool in air, away from drafts. You can use it without any grinding. Plow shares, cultivator sweeps and other parts that are worn by abrasion of the earth can be hard faced in the same way.

A grader blade, like the one shown in Fig. 2, can be hard faced the same way. Of course, the job will take longer than the shovel because the blade is 10 ft. long. If the blade gets too cool, direct the flame at the edge of the puddle and at the metal just ahead.

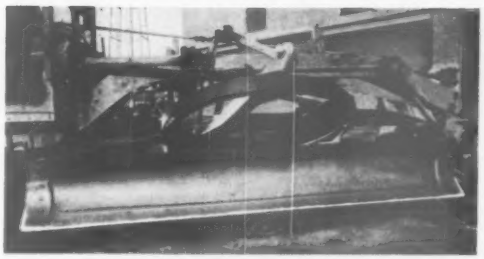


Fig. 2 A 10-ft. long grader blade, like this, can be hard faced the same way

Do not try to push or guide the puddle with the rod. The puddle will spread when the metal ahead of it is at the correct temperature. Build up the deposit about 1 in. wide and $^1/_8$ in. thick. Hard face about 2 in. on each side of the blade.

Arc-Welded Beam and Column Framing

Studies in structural arc welding. For silent erection . . . Arc Weld (Continued from previous issue)

IN THE upper stories of this building it was found more economical to splice the columns with direct bearing and anchor bolt details as shown in Fig. 8, bearing on the top and bottom sides of the girder, than to provide for a splice at the point of maximum moment in the 33-in. WF 220-lb. continuous girders.

Thus, milled 6-by $^3/_4$-in. bearing plate stiffeners were welded to the web of the girder between flanges to provide a full bearing support for the upper 14-in. WF 68-lb. column and the $1^1/_4$-in. cap plates were provided on the top and bottom ends of the columns to be bolted temporarily and then permanently welded to the girder flanges.

The cap plates were shop welded to the ends of the column sections and then permanently field welded to the girder flanges after plumbing and aligning the structure.

Another interesting method of providing for continuity in both the beams and the column is shown in Fig. 9.

This detail was proposed for the main framework of a large British nylon factory of all-welded construction three stories high and 1000 ft. long by 324 ft. wide. The story heights were 19 ft. for the first story and then two more stories at 13 ft. from floor to floor.

The columns were spaced on 25- by 54-ft. centers, and were made by shop welding three plates together with plate

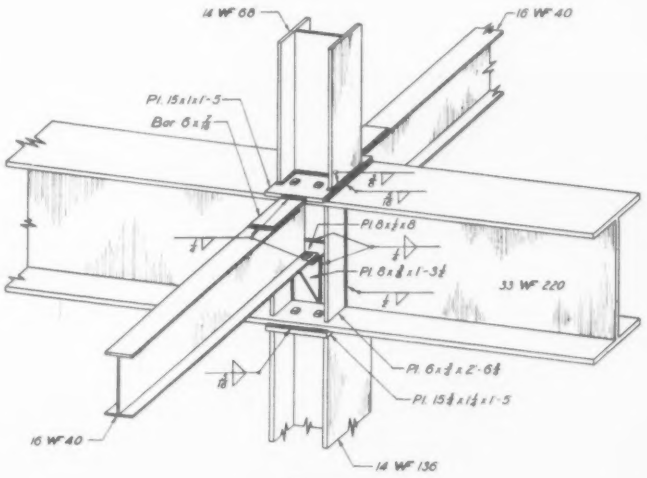


Figure 8

Photographs and data supplied through courtesy of The Lincoln Electric Co., Cleveland 1, Ohio.

brackets welded into the plane of the column flanges to form an integral portion of the column flange projecting out to support the girders. Thus, the plate brackets can be made to support very heavy loads and develop practically any strength that the columns will hold.

The main girders of this structure were also made in unique fashion as twin continuous girders supported on the bracketed column flanges. In this fashion the girders run by both sides of the column without any interference and the columns can be completely fabricated in the shop to erect as single units, three stories high in the field without any field splices. The girders are made to cantilever past the columns with field splices at the points of inflection.

These details saved from 4 to 5% of the weight of conventional riveted columns and about 15 to 20% of the weight of the girders and yet cost no more to fabricate than the prevailing price per ton for columns and girders of riveted design.

The loads on the individual columns varied from 225 to 765 tons per column and, since all the columns were fabricated as three-plate sections, the plate sizes for the column sections were varied to suit the individual load requirements of each story.

Figure 10 is also similar except in this instance the columns are spread and single web, continuous girders run through the four angle column sections.

This arrangement was also designed in Los Angeles as an extension of the Los Angeles Bell Telephone building by Maurice Sasso.

The main girders are supported on the cross-channel batten plates and run directly through the main columns. The four angle column sections are intended only to provide for temporary supports during erection and then later as composite steel and concrete columns after the columns and beams have been encased in concrete for fire protection.

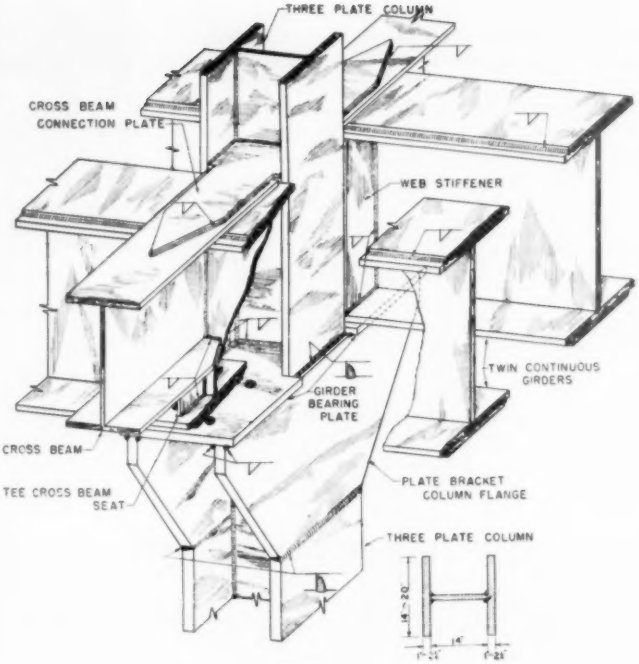


Figure 9

Figure 11 is a sketch of the continuous beam-to-beam framing detail that was also used in this building. The top flanges of the beams are extended across the top flange of the girder and butt weld together on the center line of the main girder. The additional negative moment flange requirements are made up by cover plates added to the edges of the flanges and the intensity of stress on the butt weld is reduced in proportion to this extra flange material. The web and bottom flanges of the beams are cut to the profile of the main girders. During erection the beams are supported by the top flanges while the webs are being welded to the main girders for shear.

This concludes the current series of beam and column framing details.

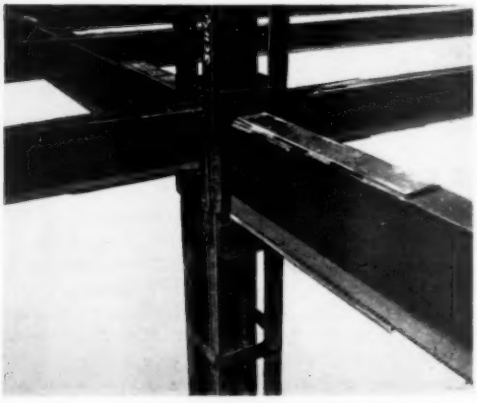


Figure 10

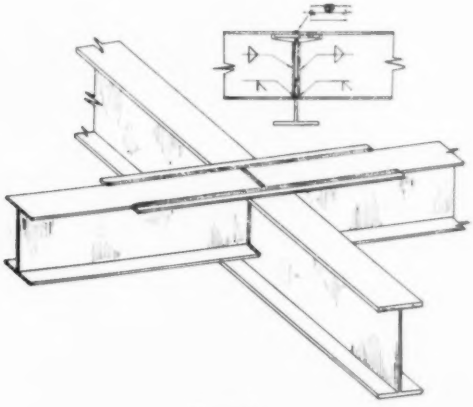


Figure 11

the AMERICAN WELDING SOCIETY

activities • related events

30th Annual Meeting Huge Success

The 30th Annual Meeting of the AMERICAN WELDING SOCIETY can be considered as highly successful from every angle. The Meeting was held during the National Metals Congress and Exposition in Cleveland.

The Exposition, always the chief drawing card of the Congress, was particularly noteworthy this year from the point of view of the welding industry in the many new products that were shown. A good many of the demonstrations were working exhibits so that the engineer could actually see the workings and benefits of these new products and processes. There were many refinements and improvements of recently developed processes.

An outstanding feature was the large number and variety of technical papers presented before the SOCIETY. Three simultaneous sessions were held all day Monday and Tuesday, and on the mornings of Wednesday, Thursday and Friday. More than half of the 77 papers were available in preprint form either in the September or October JOURNALS or in a special preprint. Others will be published as rapidly as possible. Registration started on Sunday afternoon and continued throughout the week. A registered attendance of over 1835 people a new high was chalked up at the Hotel Cleveland, headquarters of the SOCIETY.

Prizes and Awards took place on Monday evening. Announcement of the recipients of these prizes and awards are given elsewhere in this issue. Monday evening was also the occasion of the annual presentation of the Adams Lecture. This year the lecture was presented by Prof. W. M. Wilson on, "The Advantages and Disadvantages of Arc Welding as a Means of Fabricating Steel Structures. Professor Wilson presented this difficult subject in his usual able manner.

The combined social affair took place on Tuesday evening. This started with the President's Reception and was followed by cocktails and an informal dinner and dancing. About 400 people participated in this social function. A good time was had by all.

Continuing a plan started last year the Educational Committee put on a series of well attended lectures on the Fundamentals of Welding Design by an outstanding authority in the field, Harry W Pierce, Assistant to the President, New York Shipbuilding Corp.

Another highlight of the Convention was the special luncheon given in honor of Miss M. M. Kelly, Secretary Emeritus of the AMERICAN WELDING SOCIETY. A brief description of this special occasion will be given in the next issue of the JOURNAL.

The usual University Research Conference on Wednesday evening brought together some 40 professors and a number of other scientists. The gathering was particularly honored by the presence of Mrs. C. F. Tipper, a noted scientist of Cambridge University, England. She briefly described some of the research work on the other side which closely parallels the activities of the Ship Structure Committee and the Welding Research Council in this country. On the same evening the Section Officers had their usual conference and discussed ways and means of improving the SOCIETY and making it more useful to the membership at large.

The Annual Business Meeting of the SOCIETY was held Wednesday afternoon and was followed by a Board of Directors meeting.

Thursday afternoon was given over to visits to the Exposition. A special inspection tour to the plants of the Cleveland Electric Illuminating Co. and the Fruehauf Trailer Co. in Avon Lake, Ohio, also took place on the same afternoon. About 81 people participated in this inspection trip.

A special and new feature of the Annual Meeting was an outstanding lecture by P. W. Swain, Managing Editor of *Power and Operating Engineer*, McGraw-Hill Publishing Co., who gave an educational and inspiring review of "The Importance of Welding and What It Means in Our Everyday Life." Some 125 executives and members of the SOCIETY attended this meeting.

ADAMS LECTURER

Wilbur M. Wilson

In order to honor the Founder and First President of the AMERICAN WELDING SOCIETY, the SOCIETY in 1943 created a lectureship known as The Adams Lecture. The award is made annually by the Board of Directors to an outstanding scientist or Engineer, and his lecture presents some new and distinctive development in the field of welding. This year The Adams Lecture was given by Wilbur M. Wilson, on, "The Advantages and Disadvantages of Arc Welding as a Means of Fabricating Steel Structures."

Wilbur M. Wilson, the son of Mathias and Ruth Mosher Wilson, was born on a farm near West Liberty, Iowa, July 6, 1881. He received the degree of Bachelor of Mechanical Engineering from Iowa State College in 1900. The college conferred on him the professional degree of Civil Engineer in 1914 and the honorary degree of Doctor of Engineering in 1942. He received the degree of Master of Mechanical Engineering from Cornell University in 1904.

Wilbur M Wilson

Professor Wilson served as an instructor in Mechanical Engineering at Iowa State College from 1901 to 1903, and as an Assistant Professor and Associate Professor in Mechanical Engineering during the period from 1904 to 1907. During the school year 1903-04, he held a graduate fellowship in Cornell University. He practiced structural engineering in Chicago during the period from 1907 to 1913, and served as Assistant Professor or Structural Engineering at the University of Illinois from 1913 to 1917, resigning at the latter date to enter training camp as an officer candidate.

After World War I, he returned to the University of Illinois as Associate Professor of Structural Engineering and, beginning in 1922, has held the position of Research Professor of Structural Engineering in the Civil Engineering Department of that school to the present time.

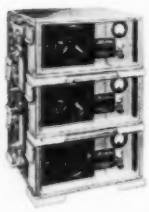
Professor Wilson is a member of many engineering societies and is well known for his many contributions to the literature of structural engineering. On two occasions, the Western Society of Engineers awarded him the Chanute Medal for the best paper of the year presented before the SOCIETY. He was also awarded the James J. R. Croes Medal of the American Society of Civil Engineers and the Wason Medal of the American Concrete Institute.

Q. CAN YOU HEAT A HIGH PRESSURE, WELDED PIPE JOINT TO 1700° F, 30 FEET UP IN THE AIR?

A. The Smith Dolan System can EASILY handle this problem of Preheating Stress Relieving and Normalizing to 1700° F on Carbon and Stainless Steels!

Boiler down-comer partially wrapped for stress relieving.

1. SAFE TO USE EASILY APPLIED ASSURED RESULTS	**Smith Dolan Heating Apparatus is so simple to handle that it can be operated by job personnel. Because it delivers consistently perfect results under safe conditions, it assures you of minimum job cost.**
2. THOROUGH PENETRATION	**It is no problem to achieve thorough heating of heavy sections with precise control in minimum time.**
3. MEETS METALLURGICAL & CODE REQUIREMENTS	**Proper heating is delivered according to set specifications and requirements of Boiler and Piping codes.**
4. LABORATORY CONTROL UNDER FIELD CONDITIONS	**Smith Dolan Induction Heating Apparatus is designed and engineered with automatic or semi-automatic controls. Therefore, you obtain accurate, consistent results under field conditions, with a permanent record of each job always available.**



NEW MODEL U-P *— Patented Smith-Dolan System, portable, low frequency induction heater, three-high stack (shown) 30 kva—10 kva per unit. Buy one or stack 2 or 3 for increased capacity. Buy what you need —build as you go.*

INDUCTION CONTROL CABINET

used with Model U-P units (shown) and Model GC Duplex 120 or 150 kva induction heaters (shown in catalog).

ELECTRIC ARC **can supply equipment for ANY TYPE OF JOB— equipment that can be *purchased outright* or *rented*. From what other source could you possibly obtain such wide latitude in planning for every job in preheating and stress relieving before welding and normalizing? Today, more than ever, Electric Arc equipment is specified where other methods are too costly or impractical. Write for informative catalog.**

ELECTRIC-ARC INC.

ELECTRIC-ARC, INC.
161 JELLIFF AVE., NEWARK 8, N. J.
Welding Equipment, Electrodes & Supplies

He was a director of the American Society of Civil Engineers from 1944 to 1947 and represented that SOCIETY as one of the Nonparticipating Science Observers who were invited by the Joint Task Force to witness the Atomic Bomb Tests at Bikini in 1946.

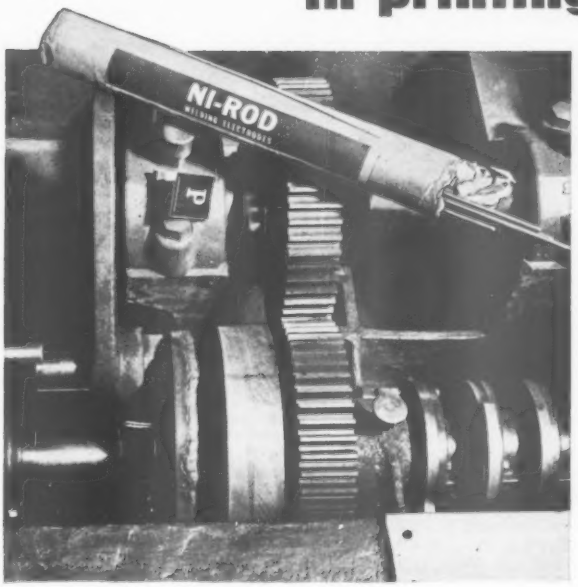
Professor Wilson is widely known for his research work in the field of structural engineering. His early work was mostly analytical. At the time this work was done, his applications of the slope-deflection method to the analysis of statically indeterminate structures were recognized as a major contribution to the literature of structural engineering. In later years, his work has been mostly experimental. He has specialized on the testing of structures and structural members as distinguished from tests to determine the mechanical properties of materials. This involved the development of laboratory apparatus which would subject structural members to the loading conditions to which they would be subjected as a member of a structure in service. This work has contributed greatly to the profession's knowledge relative to the design of rolling bascule bridges, cylindrical shells loaded as columns, multiple-span reinforced concrete-arch bridges and to the design of riveted and welded joints in steel structures. His early training in mechanical engineering at Iowa State College was especially helpful in this work.

For the last decade, Professor Wilson has devoted a major portion of his time to the determination of the fatigue strength of structural members subjected to repetitions of load.

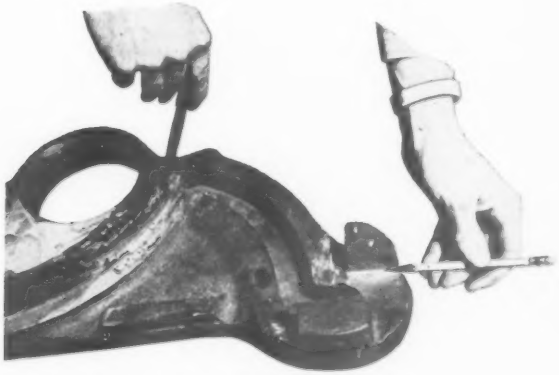
His work has enabled engineers to determine the locations where fatigue cracks are most likely to occur in old bridges, thus enabling an inspector to detect the cracks before they have developed to the point where they endanger the life of the bridge.

Professor Wilson married Teresa Stewart of Iowa City, Iowa in 1905. They have two children: Grace, an instructor, College of Engineering, University of Illinois, and Matt, an engineer with the A. P. Greene Firebrick Co., Mexico, Mo. Both children are graduates of the University of Illinois. Professor and Mrs. Wilson have five grandchildren, of whom they are very proud.

Ni-Rod *Ventured* - Time and Money *Gained* in printing press repairs



A worn cast iron cam on this Miehle vertical press was built up with beads of NI-ROD without dismantling the gear box. The welder had no previous experience with metal arc welding.



This platen cam casting from a John Thompson press had two sections broken off. Both were restored by welding with NI-ROD.

RECENTLY, a firm that specializes in the repair and reconditioning of worn printing machinery took a gamble . . . a small one, but it paid handsome dividends.

Much of their repair work consisted of brazing and gas welding broken cast iron frames and worn machine members. So welding was an old story to them. *But* . . . they had never tried metal-arc welding.

Then they heard about the fine performance of Ni-Rod* electrodes in cast-iron maintenance work. They decided to give them a trial. Result? Today they use Ni-Rod for most of their welding work. And like thousands of other shops, they find that Ni-Rod saves both time and money: gives better results with less effort.

Ni-Rod gives sound, non-porous, *machinable* welds in all grades of cast iron. Slag removal is easy. Ni-Rod is stable-arcing in all positions with either AC or DC current. Preheating or post-heating is seldom necessary . . . an important time-saving feature. You can use Ni-Rod for joining cast iron to steel, too.

Why not try Ni-Rod in your own shop . . . soon? Discover for yourself why *4 out of 5* shops re-order Ni-Rod, once they've tried it.

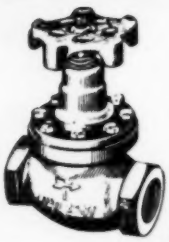
Your nearest INCO distributor stocks Ni-Rod in 3/32", 1/8", 5/32" and 3/16" diameters.

Write for your copy of the helpful new 8-page booklet: "*NI-ROD . . . a new electrode for any cast iron welding.*"

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

*Reg. U. S. Pat. Off.

REGO



GLOBE
and
ANGLE
VALVES

Diaphragm construction provides permanent seal for valve stem, eliminating necessity for adjustment or repacking as required with ordinary packed-type valves.

●

Back-seating permits replacement of diaphragm while valve is under pressure.

●

Design Working Pressure 400 psi (oil, water or gas)

●

Large Passages reduce friction losses to a minimum.

●

Sizes
3/4"
1"
1-1/4"
1-1/2"
2"

●

Write for catalog

The BASTIAN-BLESSING Co.
4201 W. Peterson Ave., Chicago 30, Illinois
Pioneer and Leader in the Design and Manufacture of Precision Equipment for Using and Controlling High Pressure Gases

Bissell Awarded Miller Medal

The Samuel Wylie Miller Memorial Medal has been awarded this year to A. G. Bissell, Civilian Head of the Welding and Metals Branch of the Bureau of Ships. The Samuel Wylie Miller Medal is awarded each year to commemorate the many unique contributions of Samuel Wylie Miller to the science and art of welding. The Medal is awarded to the person who, in the judgment of the Board of Awards, is most deserving for conspicuous contributions to the advancement of the welding or cutting of metals. There follows the remarks made by Rear Admiral Ellis Reed-Hill, U.S.C.G., Ship Structure Committee, upon the occasion of presenting the Samuel Wylie Miller Memorial Medal to A. G. Bissell, Oct. 17, 1949, Annual Meeting of the AMERICAN WELDING SOCIETY.

"I am extremely gratified to have been requested to present the Samuel Wylie Miller Memorial Award this year. I am also aware of the honor paid to the Ships Structure Committee, of which I am Chairman.

"The Samuel Wylie Miller Memorial Medal is not presented as a reward for a *specific* act or contribution to Science. It is awarded each year to the person who, in the judgment of the Board of Awards of the AMERICAN WELDING SOCIETY, has made conspicuous contributions during a *lifetime* of service in welding.

"The recipient whom we are honoring tonight has a long and outstanding record in the welding profession. His earliest work in welding was done in 1918 and he has played a leading role in the development of the art ever since. In 1920 he wrote what is believed to be the first thesis on the subject of welding to be accepted by a University for an advanced degree. His experience in welding covers both industry and government for a good many years his name—or rather his first two initials—have been a household by-word in the Welding and Metals Branch of the Bureau of Ships. Of particular interest to me and to the Ship Structure Committee, is the fact that he was one of the original members appointed to the Sub Board convened by the Secretary of the Navy in 1943 to investigate the fractures which had then started to occur in welded-steel merchant vessels. That Board was the predecessor of the Ship Structure Committee. His interest and acitivity in this work has continued to the present and he has on many occasions rendered invaluable assistance to the Ship Structure Committee in the accomplishment of its mission.

"It is with great pleasure indeed, that I present on behalf of the AMERICAN WELDING SOCIETY the Samuel Wylie Miller Memorial Medal for 1949 to A. G. Bissell."

Biographical Sketch—A. G. Bissell

Mr. Bissell is a native of New York state, receiving his early education in the public schools of LeRoy, N. Y. He graduated from the Tacoma, Wash., High School and attended the University of Washington, Seattle, Wash., from which he was graduated with the degree of B.S. in Chemical Engineering. He was elected

A. G. Bissell

to the Phi Lamda Upsilon Honorary Society of the University of Washington.

In May 1918 while in the position of Metallurgist at the Puget Sound Navy Yard, Bremerton, Wash., he was detailed to investigate the use of arc welding in the construction of steel Naval Vessels. In the course of this work, he organized the Hull Division Welding Shop, training the welders and supervisors and directing the applications of arc welding to the vessels under construction at the Yard at that time. While at the Puget Sound Navy Yard in 1920 he received the degree of Chemical Engineer from the University of Washington. His thesis "The Use of Arc Welding in Steel Ship Construction," is believed to be the first thesis on welding to be accepted by a University for an advanced degree. He participated in the early development of structural steel welding while connected with the Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa., as General Engineer speaking on this subject before engineering and technical meetings throughout the country and was actively connected with the design and erection of the first all-welded buildings at the East Pittsburgh Works and the first all-welded through plate girder railroad bridge at Turtle Creek, Pa. After leaving Westinghouse, he did consulting work in Welding Engineering in Seattle, Portland and Los Angeles. He assisted in the reconstruction of the University Bascule Bridge in Seattle on which welding and the first use of an open grating deck made it possible to widen the bridge by two traffic lanes with but a slight increase in the weight of the lifts.

Since 1936, Mr. Bissell has been connected with the Navy Dept., Washington, D.C., and at present is Civilian Head of the Welding and Metals Branch of the Bureau of Ships.

He has been a member of the AMERICAN WELDING SOCIETY since 1923, a member of the National Board of Directors, Eastern District Vice-President; first Chairman of the Washington, D. C., Section, and a

AC or DC?

The Job Determines the Type of Welder

By Burke Porter, Chief Engineer
C. O. Porter Machinery Company, Grand Rapids, Michigan

Burke Porter

Extensive changeover of our woodworking machines from castings to weldments has made advisable the construction of a new plant devoted entirely to the fabrication of our machine parts. In equipping this new welding shop, we have given considerable thought to the types of arc welders to be installed.

Should they be AC or DC?

The advice of the local Lincoln Welding Engineer seemed sound—*install both types of welders and use the type which is best suited to each job.*

Accordingly, we installed three 400-amp. Lincoln DC "Shield-Arcs" and two 500-amp. Lincoln AC "Fleetwelders."

For the bulk of our work, DC is preferable. Much of it involves outside corner welds, all-position joints, intermittent beads, light-gauge material, tubular members, and we often weld stainless steel.

On the other hand, in the welding of our bases, inside corner joints and boxed-in areas result in considerable arc blow. Under these conditions, we can use higher amperages and get faster welding and better quality with the AC welders.

In this problem of AC and DC welding, the unbiased recommendations of the Lincoln people are advantageous to us and our customers. It pays to apply the right type of welding to match the job.

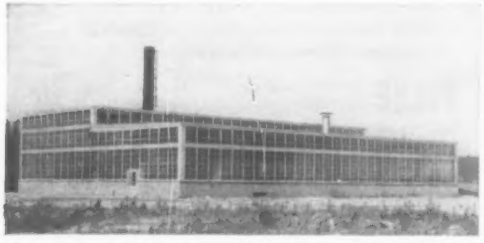


Fig. 1. New weldment plant of the Porter Machinery Co.... evidence of the belief of this company in the superiority of welded steel for its products.

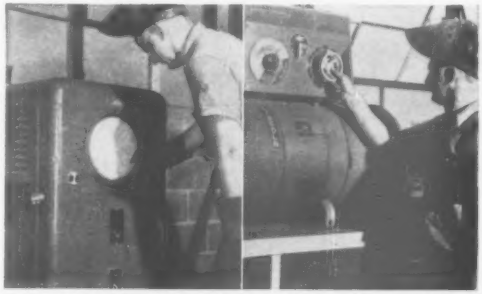


Fig 2. (Left) If arc blow is involved, the welder tackles the job with AC. (Right) If arc blow or very high currents are not involved, DC usually is best.

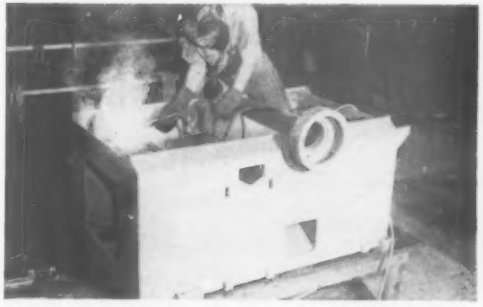


Fig. 3. Bases—where arc blow is severe—are welded with AC.

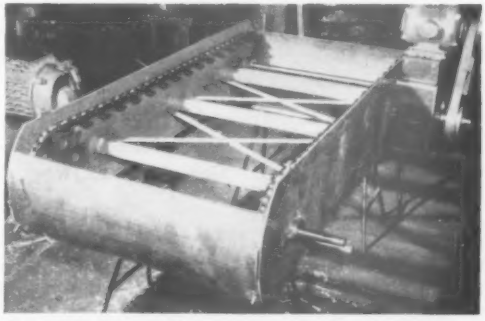


Fig. 4. Parts such as this frame are generally welded with DC.

The above is published by **THE LINCOLN ELECTRIC COMPANY** *in the interests of progress.*
Write for DC "Shield-Arc" Bul. 459 and AC "Fleetwelders" Bul. 366. The Lincoln Electric Company, Dept. 911, Cleveland 1, Ohio.

member of A.W.S. technical committees.

He was closely connected with the development of the welding of armor by the Navy before the late war and was a member of the sub-board of the Board convened by the Secretary of the Navy to investigate the Design and Construction of Welded Steel Merchant Vessels. He is a member of the Welding Committee of the American Bureau of Shipping.

In 1942 he was a recipient of the Lincoln Gold Metal and in 1946 received the Meritorious Civilian Award from the Bureau of Ships.

Amirikian Awarded Lincoln Gold Medal

The Lincoln Gold Medal is awarded each year to the author of the paper which, in the judgment of the Board of Awards, is the greatest original contribution to the advancement and use of welding. The 1949 Lincoln Medal was awarded to Arsham Amirikian for his paper, "Future Developments in Welded Steel Buildings," published in the August 1948 issue of THE WELDING JOURNAL.

Arsham Amirikian graduated from Cornell University in 1923 with the degree of Civil Engineer. After five years' employment with private companies, he entered the Government service in 1928, at the Bureau of Yards and Docks of the Navy Department in Washington, D. C. He has been with the Bureau for over twenty-one years, beginning as Assistant Engineer and advancing through the grades to Head Engineer in 1945, and for the past ten years, he has been heading the Bureau's special design section on buildings, welding, floating structures and protective construction.

A. Amirikian

He is a member of the American Society of Civil Engineers, Society of Naval Architects and Marine Engineers, Society of American Military Engineers, American Concrete Institute, AMERICAN WELDING SOCIETY, International Association of Navigation Congresses and Cornell Society of Engineers, as well as a member of many technical committees.

He is the author of the design treatise "Analysis of Rigid Frames" and about a score of technical papers.

He has conducted graduate courses in engineering design at George Washington University, Catholic University, Graduate School of Department of Agriculture in Washington, D. C., and presently he is a visiting lecturer at Rensselaer Polytechnic Institute in Troy, N. Y.

COMPLETE **CARBON BRUSH DATA**

SPECIFICATIONS FOR ALL MAKES AND TYPES OF WELDING EQUIPMENT

. . . yours for the asking

Twenty-eight pages of easily found information, complete with factory model numbers, replacement brush numbers, scaled illustrations of brushes listed, and all other necessary data. Here is a regular "Encyclopedia" of Brush information covering all types and makes of welding equipment.

SEND FOR YOUR FREE COPY NOW!

B·B·B Stands for Quality . . . EVERYTHING IN CARBON

BECKER BROTHERS CARBON CO.
3450 SOUTH 52nd. AVE. CICERO 50, ILL.

DON'T
LET IT HAPPEN
IN YOUR PLANT!

PICKLING fumes do more than irritate your nose. They carry tiny drops of acid up to the roof girders, overhead cranes, conveyors, window frames, pipes and electrical fixtures. The acid eats through paint and into steel. Rust creeps in. Things go wrong!

Don't let it happen in your plant! Use Oakite Composition No. 38, the new pickling additive that traps the acid fumes before they leave the tank.

FREE Full information about Oakite Composition No. 38. Just write to Oakite Products, Inc., 18E Thames St., New York 6, N. Y.

Machine cleaning	Tank cleaning	Electrocleaning
Pre-paint treatment	Pickling	Paint stripping
Steam-gun cleaning	Burnishing	Rust prevention

OAKITE 1909 1949 40 ANNIVERSARY YEAR

OAKITE
REG. U. S. PAT. OFF.
INDUSTRIAL CLEANING MATERIALS · METHODS · SERVICE

Technical Service Representatives Located in Principal Cities of United States and Canada

PAGE WELDING ELECTRODES AND GAS WELDING RODS

WELDING STAINLESS?

○

TO RESIST WHAT?

HEAT?

COLD?

IMPACT?

BENDING FATIGUE?

CORROSION?

WHAT KIND OF CORROSION?

○

NOW ONE MORE QUESTION:

Are you using the best electrode or rod for your purpose?

If you're not too sure, get in touch with your PAGE distributor. Either he knows or he can find out from the PAGE Field Service Man. And the PAGE distributor has a wide selection of Page-Allegheny Stainless Steel rods and electrodes, so that he can give you the one that will serve you best.

ACCO

TRADE MARK

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

Get in touch with your PAGE Distributor

Resistance Welding Awards

In order to encourage the preparation of outstanding papers dealing with resistance welding subjects, the Resistance Welder Mfrs. Assn., Philadelphia, Pa., has for several years conducted a prize contest, the awards for which are announced annually at the fall meeting of the AMERICAN WELDING SOCIETY. The total amount of the awards is $2000, and a wide choice in subject matter is allowed in order to assure eligibility to all papers which cover worth-while and significant achievements in the field.

The first prize of $750 for the best paper from an industrial source was won by J. Heuschkel and H. C. Bitzer for their paper on "Spot Weld Consistency Study," published in the October 1949 issue of THE WELDING JOURNAL. Mr. Heuschkel is manager of the Westinghouse Research Welding Section and was formerly associated with the Carnegie-Illinois Steel Corp. and the U. S. Navy Dept. H. C. Bitzer has been Laboratory Assistant in the Westinghouse Research Welding Section since returning from naval service.

The second prize for a paper from an industrial source carrying an award of $500, was won by Ivar Johnson for his paper on "Slope Control and Its Effect on Spot and Projection Welding," published in the October 1949 issue of THE WELDING JOURNAL.

After graduating from the University of Minnesota in 1924 with the degree of B.S. in Electrical Engineering, Mr. Johnson became affiliated with the General Electric Co. At present, he is in charge of resistance welding development work in the laboratory and the establishment of resistance welding information for new products and materials in the engineering and manufacturing divisions.

The third prize of $250 for the third best industrial paper was won by Frank G. Harkins of the Solar Aircraft Co., for his paper "Spot Welding Nickel and Nickel Alloys in Dissimilar Metal Combinations," published in this issue.

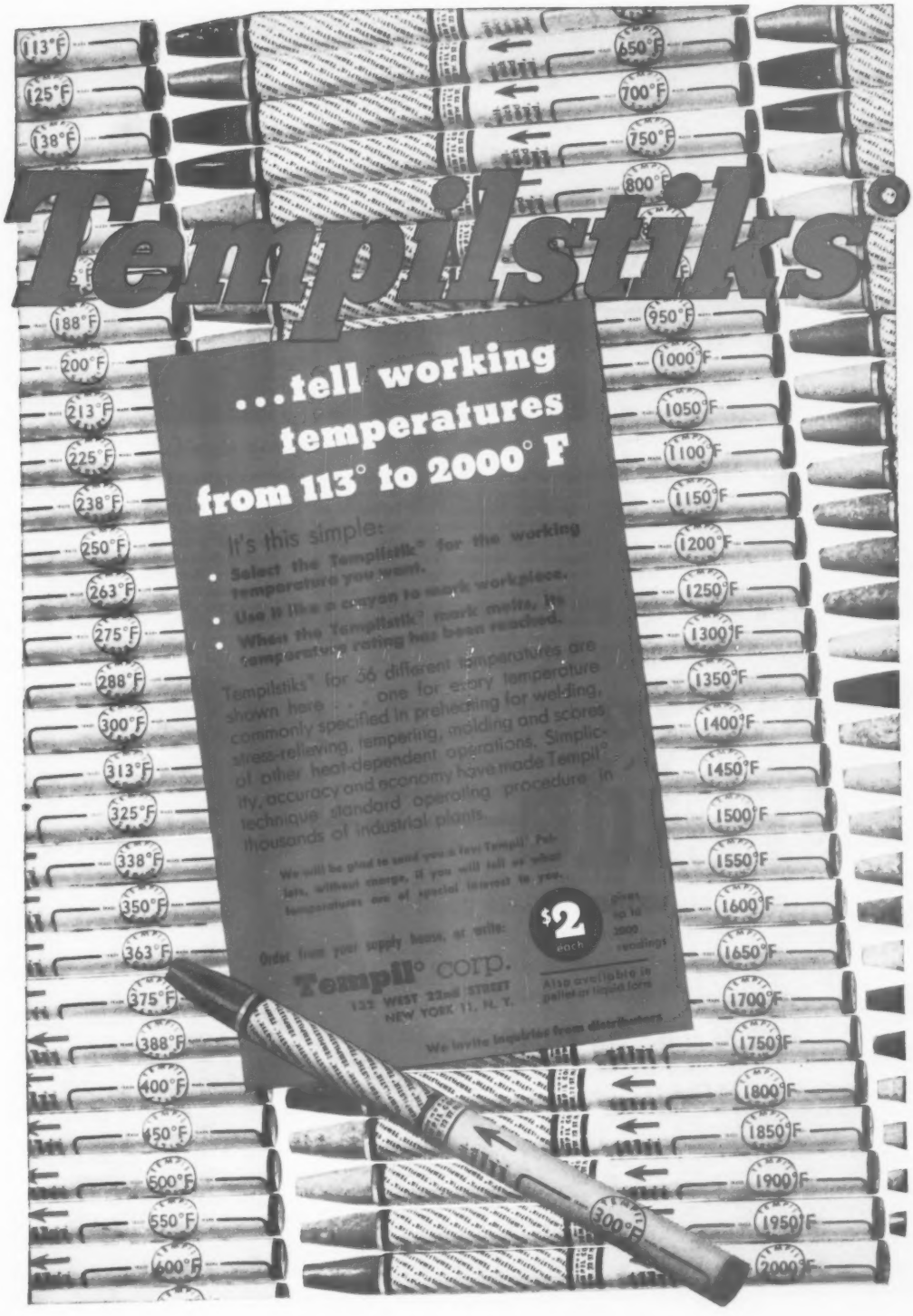
J. Heuschkel

H. C. Bitzer

Before joining the Solar Aircraft Co., Mr. Harkins was connected with the Westinghouse Electric Corp. from 1931 to 1939 in various electrical engineering capacities, then became Assistant Chief Engineer for the National Casket Co., Pittsburgh. Mr. Harkins has been associated with resistance welding for the past 18 years and is a member of several technical committees of the SOCIETY and the Welding Research Council. In 1948

INDEX TO ADVERTISERS

Air Reduction Sales Co.	Outside back cover	P. R. Mallory & Co., Inc.	1033
American Brass Company	Inside back cover	Metal & Thermit Corporation	Inside front cover
American Chain & Cable	1095	National Carbide Corporation	1098
The Auto Arc-Weld Mfg. Co.	1101	National Cylinder Gas Co.	1110 & 1111
The Bastian-Blessing Co.	1092	North American Phillips Company, Inc.	1107
Becker Brothers Carbon Co.	1094	Oakite Products Inc.	1094
Contour Marker Corp.	1115	Page Steel & Wire Division	1095
Cullen-Friestedt Co.	1108	Reed Engineering Co.	1112
Dockson Corporation	1114	Sciaky Bros. Company	1117
Eisler Engineering Co., Inc.	1104	A. O. Smith Corporation	1121
Electric Arc, Inc.	1090	Stackpole Carbon Co.	1099
Eutectic Welding Alloys Corp.	1104	Tempil° Corporation	1097
Fansteel Metallurgical Corp.	1105	Union Carbide and Carbon Corp.	1035
General Electric Co.	1102 and 1113	Victor Equipment Company	1036
Harnischfeger Corporation	1123	Wall Wire Products Co.	1114
Hobart Brothers Company	1031	Weiger Weed & Company	1105
The International Nickel Co., Inc.	1091	J. H. Williams & Co.	1104
The Lincoln Electric Company	1093	Worthington Pump and Machinery Corp.	1103
The Linde Air Products Company	1035		


Templstiks®
...tell working temperatures from 113° to 2000° F
It's this simple:
• Select the Templstik® for the working temperature you want.
• Use it like a crayon to mark workpiece.
• When the Templstik® mark melts, its temperature rating has been reached.
Templstiks® for 56 different temperatures are shown here . . . one for every temperature commonly specified in preheating for welding, stress-relieving, tempering, molding and scores of other heat-dependent operations. Simplicity, accuracy and economy have made Templ® technique standard operating procedure in thousands of industrial plants.
We will be glad to send you a free Templ® Pellet, without charge, if you will tell us what temperatures are of special interest to you.
Order from your supply house, or write:
Templ® corp.
122 WEST 22nd STREET
NEW YORK 11, N. Y.
$2 each
gives up to 2000 readings
Also available in pellet or liquid form
We invite inquiries from distributors
113°F
125°F
138°F
188°F
200°F
213°F
225°F
238°F
250°F
263°F
275°F
288°F
300°F
313°F
325°F
338°F
350°F
363°F
375°F
388°F
400°F
450°F
500°F
550°F
600°F
650°F
700°F
750°F
800°F
950°F
1000°F
1050°F
1100°F
1150°F
1200°F
1250°F
1300°F
1350°F
1400°F
1450°F
1500°F
1550°F
1600°F
1650°F
1700°F
1750°F
1800°F
1850°F
1900°F
1950°F
2000°F
300°F

Ivar Johnson

F. C. Harkins

P. Patriarca

he won the R.W.M.A. prize for his paper on "Spot Welding Schedules for Nickel and Nickel Alloys."

The first prize of $300 for the best paper from a university source was won by R. M. Curran, P. Patriarca and W. F. Hess for their paper on "Optimum Flash Welding Conditions," which was published in the Supplement of the November 1948 WELDING JOURNAL. Mr. Curran is now a metallurgical engineer with the General Electric Co., Schenectady, N. Y. Mr. Patriarca, a graduate of Rensselaer Polytechnic Institute, is a Research Assistant in the Metallurgy Department of R.P.I., and will receive his Master's Degree in January 1950. Dr. Hess is Head of the Metallurgy Department at R.P.I. and a Past-President of the AMERICAN WELDING SOCIETY.

The second prize of $200 for the second best paper from a university source was also won by R.P.I. engineers. Dr. Hess collaborated with W. J. Childs and R. F. Underhill, Jr., in writing the paper, "Further Studies in Projection Welding" published in the January 1949 issue of the *Welding Research Supplement*. Mr. Childs is now a Research Metallurgist at the Massachusetts Institute of Technology, Cambridge, Mass. Mr. Underhill is a student in Metallurgical Engineering at R.P.I.

National

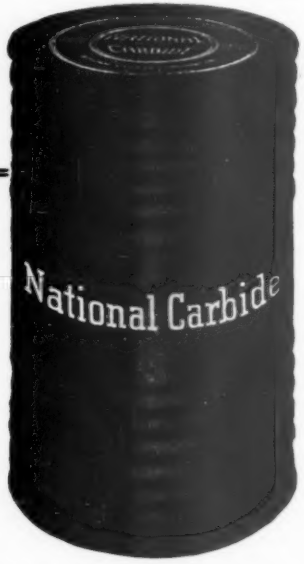
Carbide

IN THE RED DRUM

EFFICIENT

ECONOMICAL

DEPENDABLE



FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Write us for information as to nearest available stock.

60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.

STACKPOLE
WELDING SUPPLIES

WELDING CARBONS

Stackpole welding carbons are available in a complete line of carbon, carbon-graphite, and graphite types to match individual production requirements. Scientifically formulated for maximum penetration and stability at high current densities, they are supplied in practically any desired shape, taper, or diameter. Write for details.

WELDING PLATES AND PASTE

As long-time specialists in the compounding and processing of carbon in practically all of its forms, Stackpole engineers have brought welding paste and plates to a high degree of efficiency. The plates can readily be cut or filed to any shape while the paste can easily be molded. Neither one will liquify when heated, hence will not adhere to molten metal. Stackpole Welding Paste can quickly be torch-dried without danger of blistering, bubbling, or spalling.

STACKPOLE CARBON CO.
St. Marys, Pa.

WHAT DO YOU NEED IN MOLDED CARBON OR METAL PRODUCTS?

BRUSHES
(carbon, graphite, metal, and composition types)

CONTACTS
(carbon, graphite, metal, rare metal, and composition types)

BEARINGS · BRAZING BLOCKS · ANODES—ELECTRODES · CARBON SPECIALTIES
PACKING, PISTON, and SEAL RINGS · POWDER METALLURGY · RHEOSTAT PLATES and DISCS

NEWS OF THE INDUSTRY

Letter to Editor

Editor
AMERICAN WELDING SOCIETY
33 W. 39th St.
New York 18, N. Y.

Sir:

Re article by F. C. Geibig on pages 769 and 770 of August issue dealing with welding horizontal welds in vertical pipe. The method outlined would surely produce cold laps and poor penetration with resultant undercutting of upper pipe if the method of holding the torch were persisted in.

The illustration shows that the rod precedes the torch. The contrary is far better practice; back-hand welding here gives good control of the puddle at all times. This is especially important where pipe larger than illustration is used. Mr. Geibig's method will work on small pipe with a maximum of trouble and minimum of results accomplished—but it is not practical for real production.

The rod should be either upright or at an angle between upright and that shown and should *always* follow the torch and therefore permit good penetration and maximum puddle adherence to the melting end of the rod. A circular motion clockwise with the rod forms a good bead and prevents running of the molten puddle. By all means do *not* point the torch flame slightly up; it should be pointed straight in or slightly downward to secure proper penetration or surface flowing of the lower pipe.

Sincerely yours,

D. S. JENKINS, *Pres.*
Acetylene Company of Utah

New Service for Welding Contractors and Fabricators

The United States Testing Co., Inc., has recently announced the expansion of its widely used services in the control of welding operations to include the qualification of welders for welding contractors and steel fabricators. This work is being carried out in the "Testing Company" plant at Hoboken, N. J.

Furber Smith, who heads the Engineering Inspection Division of the Testing Company states that this service has been developed to meet a strong client demand. He explains that the tying up of production, equipment and operations while qualifying new welders proves very costly to the large fabricator. Similarly, at the start of new jobs welding contractors often run up costs of several hundred dollars per man and encounter costly days of delay and confusion.

The new service permits the employer to send the prospective welder employee to the United States Testing Company plant. Here the qualification tests are made and the weldments tested in a continuous operation. Certificates are issued to cover the qualified men. Twenty-four to forty-eight hours covers the operations at a considerable savings in cost. Observations of such operations by state municipal and special code agencies is freely permitted. All equipment and facilities are supplied except personal clothing.

August Jump in Resistance Welding Sales

August sales of resistance-welding machines were 81% ahead of July, The Resistance Welding Institute, Cleveland, reported recently. Actual shipments rose 70% during the same period, with cancellations dropping more than 12%. Shipments of electrodes increased 20%.

The unpredicted increase in the sale of resistance welders brings to an end a steady decline which began earlier this year, the Institute disclosed. Resumption of large-scale purchases of resistance welders is viewed as assurance that metal-fabricating industries are planning aggressive development of today's competitive consumer markets.

Examples of this trend are seen in the actions of the automotive, refrigeration, stove, television and appliance industries which contemplate near-record production quotas for the last quarter of the year, barring a strike, the Institute said. Use of resistance welding equipment is normally accepted as an accurate barometer of the economic health of these industries —which are the largest users of resistance welding—since increased use of welding always indicates increased production planning, the Institute added.

New Research and Development Laboratories, Foote Mineral Co.

Foote Mineral Co., Philadelphia, Pa., well-known manufacturers of lithium, strontium and tungsten chemicals; metals and alloys, ceramic and electrode-coating materials and refined ores, have announced purchase of the Easttown School Bldg., Berwyn, Pa. Plans are under way for conversion of this three-story brick structure for scientific research and development purposes covering work carried out by their Research and Development Department. The location is well suited for this purpose, being well provided with public transportation, located in a rural environment in attractive surroundings and serviced with adequate city utilities. The building is situated in the center of a 1.6 acre plot, occupying an entire block and elevated at some distance from the Lincoln Highway. Situated between the Main Office of the Company at Germantown, Philadelphia, Pa., and the plant at Exton, Pa., easy access is obtained with Management, Sales and Production.

Adequate laboratories, library, shop facilities and special equipment will be provided to carry out present and future research and development programs concerned with development of new and improved products and enhancement of quality and markets for present products in the fields of chemicals, metals and alloys, welding rod coatings, ceramic glazes, enamels and bodies as well as engineering studies related to improvement in equipment design and process control.

The ground floor will include welding laboratory, ceramics office and laboratory, machine shop, minerals separation laboratory, furnace room, crushing and grinding laboratory, storage rooms and heating plant. A small automatic elevator is provided for transportation of materials from the ground floor to the upper two floors. On the first floor is located the reception room, clerical and secretarial offices, the Manager's office, the library, engineering office, metallurgical laboratory and stock rooms. The second floor will be used for chemical investigations and will include analytical, inorganic, physical and organic chemistry laboratories, glass blowing room, drafting and design room, offices and stock rooms.

Dr. S. C. Ogburn, Jr., a Director of the Company, as Manager, Research and Development, will be in charge of all activities in this field carried out by the Company.

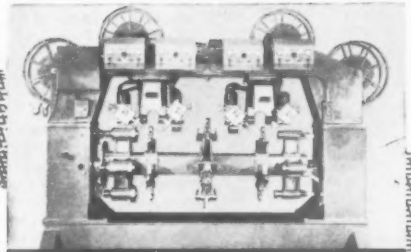
Lehigh and Bethlehem Steel Cooperate in New Metallurgy Course

Lehigh University, in cooperation with Bethlehem Steel Co., will inaugurate a new program of practical study in metallurgical engineering in the fall semester of 1950, according to a joint announcement issued by Dr. Martin D. Whitaker, president of the university; and S. J. Cort, Vice-President, Steel Div., Bethlehem Steel Co.

The new graduate curriculum will lead to the degree of Master of Science in Metallurgical Engineering Practice. It is patterned after the School of Chemical Engineering Practice at the Massachusetts Institute of Technology.

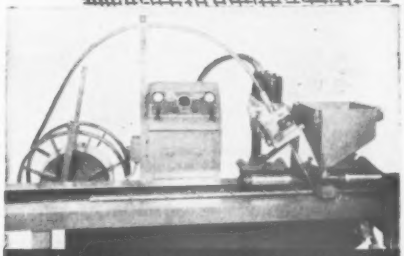
In addition to facilities on the Lehigh University campus, a field station will be established in the local plant of the Bethle-

Versatile

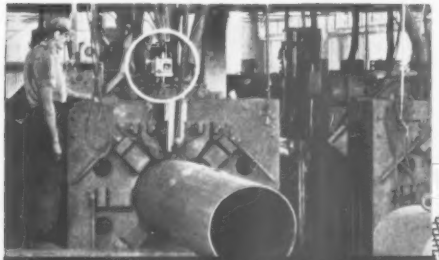


Four Auto Arc Welding Heads automatically weld spring pads on passenger car rear axle housing. Production rate is four housings per minute; welding cycle is 11 seconds per housing.

THE AUTO ARC WELDING HEAD AND CONTROLS



An Auto Arc Welding Machine for fabricating augers. The auger moves under the arc for welding the flight to the tube. The machine may be set for continuous welding.



Auto Arc Welding Heads are utilized in the continuous production of large diameter, high pressure pipe. Both A. C. and D. C. welding are used, with each arc supplied from a 1500-ampere capacity unit.

is the word for AUTO ARC

The versatility of the standard Auto Arc Welding Head is illustrated by the range of applications. The production of 16 open-arc welds per minute with four heads requires good arc starting features. Another installation with two heads starting simultaneously with 380 amps. A. C., submerged-arc on $^{5}/_{32}$" electrode, has a welding cycle of 30 seconds.

Continuous welding is maintained in a pipe mill where uniform arc control is necessary to secure desired penetration. After welding, the pipe is expanded hydraulically with pressures of 1500-2000 lbs. p.s.i.

Auto Arc equipment is also successfully operating on steel mill applications of hard surfacing materials in high temperature zones.

Where automatic arc welding is applicable to your production, let our engineers estimate its economy.

THE AUTO ARC-WELD MFG. CO.

8007 GRAND AVENUE • CLEVELAND 4, OHIO

Give your key men the up-to-the-minute facts on . . .

RESISTANCE WELDING

New fact program helps cut costs in your plant

Up-to-date knowledge of modern resistance welding is a *must* for your key men. Get this money saving information to them *now!*

IT'S EASY—General Electric has prepared all the facts in an easy-to-take, *visual* manner that's ideal for getting new ideas across *fast.*

Here's what the resistance welding program offers:

1. A fact-packed manual detailing the methods, practices, and equipment of *modern* resistance welding. It spells out objectively—*without sales bias*—the many ways in which this versatile industrial tool cuts costs and increases speed.

2. A full-color, sound motion picture, running about a half hour, showing how resistance welding solves problems similar to yours.

3. Fully-illustrated highlights booklets for individual study and review.

Convince yourself first—

We want you to judge for yourself whether the resistance welding program will pay off in your plant. That's why we offer business executives this chance to examine the *Resistance Welding Manual* without cost.

Showings cost you nothing. With your manual, we'll tell you how to arrange for a FREE film showing.

FREE
TO BUSINESS MANAGEMENT

Attach to your business letterhead

General Electric Co.
Section L 684-3
Schenectady 5, N. Y.

Please send me a sample copy of the G-E *Resistance Welding Manual* without cost or obligation, with details on how I can arrange for a FREE SHOWING of the film. (Extra copies at regular manual price—$1.00.)

Name _____ Title _____

Company _____

Street _____

City _____

GENERAL ELECTRIC

hem Steel Co. Dr. Robert D. Stout, associate professor of metallurgy, will be the director of the field station. He will be assisted by John H. Gross, instructor in metallurgy. Dr. Charles H. Herty, assistant to Mr. Cort, will be the company's liaison man at the field station.

Dr. Herty, commenting on this new industry-education cooperative project, said, "We are glad to participate in this unique approach to metallurgical education. Five months' work in the application of metallurgical methods on full-scale plant equipment, followed by a semester of specialized graduate work, will most certainly give these students a broader, but at the same time more intimate, view of the problems encountered in operations. The steel industry should benefit from the acquisition of men with this type of training."

J. M. Sylvester, general manager of the Bethlehem Plant, has pointed out one particular advantage the plant offers as a location for advanced training in metallurgical engineering. "In addition to standard carbon steels, the Bethlehem Plant produces a variety of alloy, tool and special steels," Mr. Sylvester said. "This means a wide range of metallurgical problems, offering exceptionally broad training to those students who work at the field station to be established here."

Dr. Stout, an authority on welding, is a graduate of Pennsylvania State College. Before joining the Lehigh faculty ten years ago he served as a metallurgist for the Carpenter Steel Co., Reading, Pa., from 1935 to 1939. With two other metallurgists, he was awarded the Lincoln Gold Medal in 1943 for conspicuous advancement of the science of welding.

He is chairman of the University Research Committee of the AMERICAN WELDING SOCIETY, with research projects at 50 American colleges and universities. He is a member of Tau Beta Pi, national honorary engineering fraternity; Phi Kappa Phi, scholastic honor society; Sigma Gamma Epsilon, geology, mining and metallurgy recognition society, and the American Society for Metals.

In outlining the course, Dr. Gilbert E. Doan, head of the department of metallurgical engineering at Lehigh, stated that students will spend 24 weeks at the field station installation. "The work performed will consist essentially of original investigations of a development and plant test nature," said Dr. Doan.

"Some of it will be basic metallurgical engineering, which may be followed up by practical application in the industry. Other problems will be of immediate plant interest, the request for the work or investigation originating directly with the plant superintendents. Such tests will not be routine, but directed toward developing some improvements in plant operation."

After practical work is completed at the field station, students will be required to carry a curriculum of 15 hours at Lehigh during the Spring semester. This will include a required laboratory thesis, nine hours of metallurgical engineering courses, and one free elective. Enrollment in this course will be limited to 10 graduate students.

Lincoln Foundation Announces Awards for Designs of "Welded Bridges of the Future"

"Bridges don't fly but bridge builders nevertheless can take a note from the boards of airplane designers." This was the comment of a member of the Jury of Award in announcing the results of the Lincoln Arc Welding Foundation's award program, "Welded Bridges of the Future."

Recently announced were awards totaling $6250 to bridge designers for the best designs of a two-lane, 120-ft. deck highway bridge of all-welded construction and utilizing where necessary the designer's ideas for new steel shapes that could readily be produced for the more efficient use of steel. The program was sponsored by the Lincoln Foundation of Cleveland, Ohio, to offer an incentive to engineers to design bridges especially for welded fabrication and to explore the future of bridge design with thinking not bound to the restrictions of tradition that now limit work in this field.

The future bridge designs, submitted from 25 different states, were clearly influenced by the type of structural engineering that has created the modern airplane. The successful welding of strong rigid airplane frames has suggested to bridge designers a typical bridge of the future which is a solid single unit more like a machine or automobile frame, instead of a structure built up by bolting or riveting one piece to another. The welded bridges of the future will be lighter, stronger and less expensive.

The $3000 First Award went to Thomas C. Kavanagh, a professor of civil engineering at Pennsylvania State College, State College, Pa. The winning design uses a compact triangular-shaped steel frame to support the bridge roadway. Taking advantage of two new steel shapes, devised by the designer, as well as the economy and facility of welded joints, the airplane-like frame results in a simplified lightweight, low-cost bridge of graceful and slender appearance.

The Second Award of $1500 was received by Angel R. Lazaro, Jr., Malabon, Rizal, Republic of the Philippines. Lazaro has just received a Master's degree in Civil Engineering from the State University of Iowa, Iowa City, and is now studying construction methods with army engineers in Portland, Ore. The second-place design features a new Y-shaped steel member which serves the functions normally provided by several different members. It reduces the number of steel pieces handled, the weight of steel and the amount of welding while doubling the utility of the material used.

The $750 Third Award went to Fred C. Miller, consulting engineer, Toledo, Ohio. Miller's design employs a special shaped piece which facilitates welding the steel pipe used for the bridge members. Besides a clean, pleasing appearance, the use of welding to join tubular members means fewer pieces of steel to handle and less cost per ton. The use of pipe in structures, possible because of welded connections, provides a better distribution of metal to resist stresses and results in less weight.

Production Up 50%
Labor Costs Down 50%
OUR CLAIM . . .
PROVEN BY OUR CUSTOMERS

PRODUCTION UP AT BLACK, SIVALLS & BRYSON, INC., KANSAS CITY, MO.

"The Worthington-Ransome turning rolls shown in the picture permit efficiency on repetitive work up to 90% and better—based on accurately measured arc-time. This might compare with 10 to 15% efficiency *without* the turning rolls."

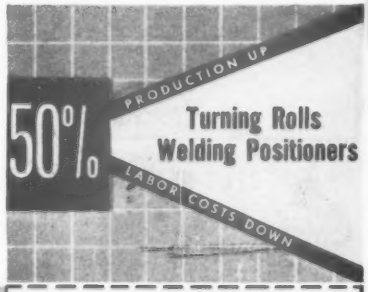
LABOR COSTS DOWN 50% AT DALLAS TANK COMPANY, DALLAS, TEXAS

"The savings resulting from the use of Worthington-Ransome turning rolls result in a reduced labor cost of approximately 50% over hand methods. We have found your equipment to be entirely satisfactory and to give long maintenance-free service."

Time saved when Worthington-Ransome Turning Rolls "handle" the work for you means *more arc time* per day. All welds are made in the "down hand" position with heavier electrodes for neater, better welds.

The improved Worthington-Ransome line includes three models, with standard capacities from 3 to 75 tons, up to 14 feet in diameter, stationary or self-propelled. (Rolls for heavier or larger work also available.) Also: positioners with capacities from 100 lbs to 20 tons.

Y 9.4



WORTHINGTON

WORTHINGTON PUMP AND MACHINERY CORPORATION

Welding and Assembly Positioning Equipment Division

DUNELLEN, NEW JERSEY

Worthington Pump and Machinery Corp.
Dunellen, N. J.

Please send Bulletin 228 on Worthington-Ransome Turning Rolls.

NAME .....

COMPANY .....

ADDRESS .....

The welded bridge of the future will not fly like a B-36 Bomber, but its steel framework, because of its welded construction, will have the same graceful appearance, strength, rigidity and light weight

An artist's conception of two of the award designs recently announced by the Lincoln Foundation for its "Welded Bridges of the Future" Program. Design on the left received the first award of $3000. Design on the right Honorable Mention

Ten honorable mention awards of $100 each were also made for other outstanding bridge designs. Triangular trusses, tubular trusses and arches, closed box sections constructed of sheet metal cells, longitudinal box sections with cantilever brackets making a "backbone and rib" type of bridge, and multiple longitudinal frames with exceptionally thin material, were some of the new design ideas developed in award papers. Awards were made to designers in Holland, Canada and South Africa.

According to the Jury of Award, the many excellent bridge designs submitted contained new ideas which it is believed will influence engineering and specifications in the bridge field. Many of the new shapes evolved for the program indicate clearly the fact that present structural shapes were not designed for the most economical distribution of metal now possible with welding, but were dictated by the then-existing means of fabricating.

While the selection of award designs by the Jury is not an endorsement by the Jury or by the Foundation of any of these new ideas presented, it is felt that many point the way to the welded bridge of the future.

The Rules Committee and the Jury of Award consisted of: Wilbur M. Wilson, *Chairman*, Research Professor of Structural Engineering, University of Illinois, Urbana, Ill.; Dr. E. E. Dreese, Chairman Board of Trustees, Lincoln Foundation and Chairman, Department of Electrical Engineering, Ohio State University, Columbus, Ohio; Harry C. Boardman, Director of Research, Chicago Bridge and Iron Co., Chicago, Ill.; Prof. James G. Clark, Department of Civil Engineering, University of Illinois, Urbana, Ill.; John I. Parcel, Consulting Engineer, Sverdrup and Parcel, St. Louis, Mo.; Lee E. Philbrook, Asst. Bridge Engineer, Illinois State Division of Highways, Springfield, Ill.; and Prof. Frank W. Stubbs, Jr., School of Civil Engineering and Engineering Mechanics, Purdue University, Lafayette, Ind.

WELDING CONNECTORS
Saxe System Welded Connection Units
for welded assembly

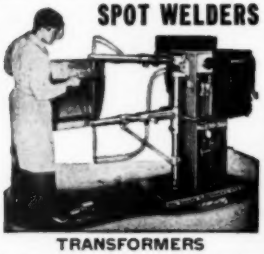
Saxe Units place in position and securely hold together structural parts to be welded.

As used in many welded structures they *eliminate all hole punching* producing an economical, rigid, safe and quickly erected structural frame.

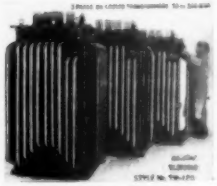
"Write for 58 pg. Manual containing full engineering design information for welded structures."

J. H. Williams & Company
Buffalo 7, New York

G. D. Peters Company
Montreal 2, Canada
Canadian Representative



SPOT WELDERS
OF ALL TYPES
SIZES 1/4 TO 300 KVA.
FOR MANUAL, AIR, MOTOR, OR ELECTRONIC OPERATION,
also BUTT, ARC, and GUN WELDERS



TRANSFORMERS
For Furnaces, Lighting, Distribution, Power, Auto Phase Changing Welding, and Special Jobs
AIR, OIL and WATER COOLED.
Sizes 1/4 to 300 KVA.

EISLER ENGINEERING CO., INC.
CHARLES EISLER, PRES.
779 South 13th St. (Near Avon Ave.) NEWARK 3, N. J., U.S.A.

for every WELDING job

SOLVE your metal joining problems the easy EUTECTIC® way, and do every job better at less cost.

EUTECTIC LOW TEMPERATURE WELDING ALLOYS® are truly amazing in performance . . . reduce risks of burning, distortion and dangerous stresses . . . are faster, surer, safer.

EUTECTIC offers a large selection of specially designed alloys—over 100—that bond at surprisingly low, harmless heats. You'll find them splendid on any metal or combination of metals . . . *and simple to use with your arc machine or torch.*

WE'D LIKE TO HEAR YOU SAY: "O. K. EUTECTIC, PROVE IT!"

Call our nearest FIELD MANAGER for FREE DEMONSTRATION IN YOUR PLANT. Eutectic Field Engineers, located across the nation, are at your service . . . see your local PHONE DIRECTORY or contact OUR MAIN OFFICE.

®EUTECTIC is unique — covered by several U. S. and foreign patents. Trade Mark, shown above, is registered at U. S. Patent Office.

Call, write or wire **EUTECTIC WELDING ALLOYS CORP.** 40 Worth St., N. Y. 13, N. Y. (Phone Barclay 7-5832)
Customers Service Department

Eutectic Welding Alloys Corp., 40 Worth Street, New York 13, N. Y. WJ

Yes! Send me . . . without obligation . . . full information on the advantages of EUTECTIC for the following application:

I would like to discuss EUTECTIC with your nearest Field Manager . . . without cost or obligation.

Name .....
Address .....
City ..... Zone ..... State .....

a new edition

of

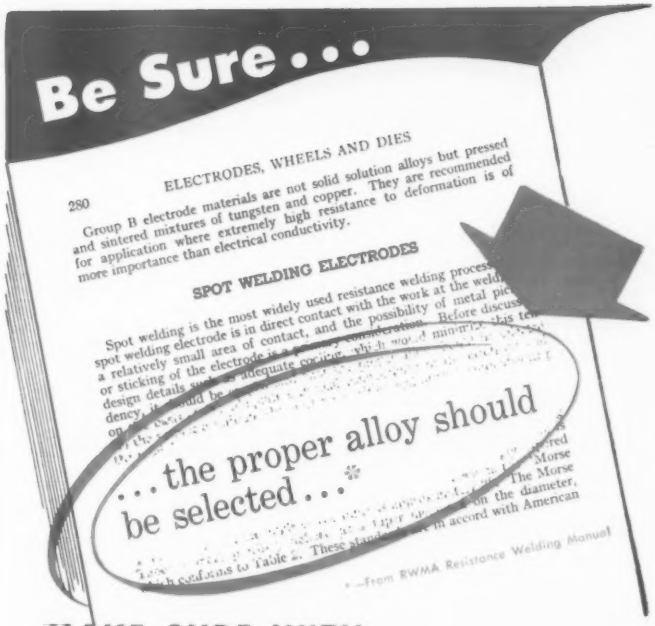
Welding Metallurgy

First published in 1940, this book has had several printings and has been distributed all over the world. To bring up to date, Mr. G. E. Linnert has prepared an extensive revision so that the new edition has 505 pages—150 pages more than the first edition. Many new illustrations have been added to bring the total to 203.

Material has been added to cover the new processes such as inert gas metal-arc welding; material has been added to provide greater coverage of the stainless steels.

A list of books is given at the end of each chapter for those especially interested in the subject covered by that chapter. Questions for school use are grouped together at the end of the book; they can be used for home study as well.

$2.50 per copy. Order through American Welding Society, 33 West 39 Street, New York 18, N. Y.


Be Sure . . .
280 ELECTRODES, WHEELS AND DIES
Group B electrode materials are not solid solution alloys but pressed and sintered mixtures of tungsten and copper. They are recommended for application where extremely high resistance to deformation is of more importance than electrical conductivity.
SPOT WELDING ELECTRODES
. . . the proper alloy should be selected . . .
—From RWMA Resistance Welding Manual

MAKE SURE WITH WEIGER-WEED SPOT WELDING TIPS

For top production speed, with fewer dressings be sure you choose the proper alloy for every spot welding job. When properly applied Weiger-Weed Tips assure longer life, sounder, cleaner welds—at lower cost! Standard Weiger-Weed tips, pointed, dome, flat, offset are available from stock—also many irregulars. Specials are promptly produced from specifications. Weiger-Weed supplies electrodes in 13 alloys of proven correct properties for each and every requirement of spot, seam, flash, butt, and projection welding. WW-1 Metal, for example, is best for welding scaly metals, galvanized iron, terne plate, tin plate and other coated metals, aluminum and its alloys. WW-2 Metal gives better performance on cold rolled steel, pickled hot rolled steel, nickel, cupro nickel, nickel silver, chrome plate, phosphor bronze, silicon bronze alloys, stainless steel, etc.

You'll also be interested in the line of Weiger-Weed Water-Cooled Holders—today's outstanding leakless holders—always trouble free. Weiger-Weed & Company, Division of Fansteel Metallurgical Corporation, 11644 Cloverdale Ave., Detroit 4, Michigan.

11506-B

Send for new Bulletin 14.650 with diagrammed illustrations, tables, and price lists.

WEIGER-WEED TRADE MARK

ONE OF THE FANSTEEL INDUSTRIES

Resistance Welding ELECTRODES
DIES • TIPS • WHEELS • HOLDERS

NEW LITERATURE

50 Years—New York Shipbuilding Corp.

A deluxe book commemorating 50 years of the New York Shipbuilding Corp., Camden, N. J., has just been issued by that Corporation. It is handsomely illustrated. It deals with the development of shipbuilding in this country since the early days and particularly during the last 50 years. It covers the work of the New York Shipbuilding Corp. in World War I and World War II and its activities since the cessation of hostilities. An interesting chart is included showing the tonnage of merchant ships and naval construction during each year of the 50 years and the total number of employees. The number of employees reached a peak of 34,000 during World War II. The current number runs between four and five thousand.

We congratulate the New York Shipbuilding Corp., on its 50th Anniversary and on the publication of this handsome book.

SR-4 Strain Gage Catalog

A new 12-page catalog of Baldwin SR-4 ® bonded resistance wire strain gages, illustrated by line drawings distinguishing 11 types of gages and listing 102 standard gages, is announced by the Testing Equipment Dept., The Baldwin Locomotive Works, Philadelphia 42, Pa. These gages are classified by types of wire and cementing materials to be used. A single table gives electrical resistances, gage factors, dimensions and prices. The catalog also lists prices of all SR-4 equipment and accessories used with the gages. A list of "things to consider in the selection of SR-4 strain gages" with references to Baldwin bulletins in which further information can be obtained, is also included.

In general, the catalog shows extensive price reductions from last year, reflecting a growing confidence in these gages and methods of using them. The resultant growing demand for them permits the economies of a larger scale of production, which can be passed on to users in spite of higher costs of materials and labor.

Applications of Ohio Products

The variety of usages of Ohio Fasteners and Fittings for projection and spot welding are so numerous that the Ohio Nut and Bolt Co., of 33 First Avenue, Berea, Ohio, has had a pamphlet, *Bulletin No. 496*, entitled "Applications of Ohio Products" made up to illustrate a few.

The applications shown on pages 2 and 3 are specimens of fasteners and fittings for projection welding. Part of page 4 illustrates the new Ohio line of fasteners and fittings for spot welding and the use of Ohio end weld studs for projection welding.

The applications shown are typical of thousands being made daily throughout American industry.

Spiral Weld Pipe

A new *Bulletin No. 493* issued by Taylor Forge and Pipe Works, announces that Taylor spiral-weld pipe is available and that prompt deliveries can be made in any quantities from two conveniently located plants in Carnegie, Pa., and Fontana, Calif.

The Bulletin shows the sizes and wall thicknesses which are available and also shows Taylor Forge fittings and flanges which are intended for use with spiral-weld pipe. Also listed are many typical applications for this lightweight, great strength pipe.

Machine Gas Cutting Folder

Air Reduction, manufacturers of industrial gases and welding equipment, has announced the publication of a new 12-page descriptive folder about two of their pantagraph type gas-cutting machines, the Oxygraph and the Travograph.

The folder covers the field of application of the machines, presents a list of the distinctive features of each machine, and includes several pages showing the machines at work on typical jobs.

One page is devoted to the four tracing devices used in machine gas cutting, the electronic, magnetic, manual and spindle.

Copies of this folder (Form No. ADC 628C) may be obtained without charge by writing Air Reduction, 60 E. 42nd St., York 17, N. Y., or the Airco sales office nearest you.

A Century of Progress

Leading industrialists of New England, customers of the Austin-Hastings Co., Inc., of Cambridge, Mass., will soon receive copies of a 40-page linen-bound book, *A Century of Progress*. Published by the century-old firm, the book is an interesting account of the company's development since its founding in 1849.

Refreshingly unlike so many anniversary publications, *A Century of Progress* outlines only briefly the major events within the firm through the years, and devotes ample space to the vital facts of the company's present activities.

Illustrated with photographs of personnel, and listing the complete lines of tubing, sheet metal, tool steel and machine tools—metal working and welding equipment for which Austin-Hastings are the exclusive distributors in New England—the book will serve as a useful reference for industrial executives and purchasing agents in this six-state territory.

Selector Chart

A new "Selector and Comparison Chart of Hardfacing Rods and Electrodes" has been released by the American Manganese Steel Division of American Brake Shoe Co. Copies are now available. Ask for *Bulletin CC-3*. Send your request to American Brake Shoe Co., 230 Park Ave., New York 17, N. Y.

This chart lists each of Amsco's welding rods and electrodes and indicates the type of service for which each is designed. Metallurgical and physical descriptions of each rod are so arranged as to simplify selection by the user of the right rod for the right job. For comparison purposes, competitive rods which are the closest equivalents for the service noted, but not necessarily of the same composition or performance as Amsco rods, are also listed.

Design for Welding

Availability of a 32-page booklet explaining and illustrating advanced techniques in the resistance welding processes has been announced by The Resistance Welding Institute of Cleveland, Ohio.

Titled, "Design for Resistance Welding," the publication covers the theory and application of spot welding, seam welding, projection welding and butt welding.

Liberally illustrated with 61 drawings and photographs, the booklet contains 11 helpful tables for the guidance of resistance welding users.

Copies are available by writing to The Resistance Welding Institute, Hartman Bldg., Detroit Ave., at Warren Rd., Cleveland 7, Ohio.

1949 Addenda to the 1946 Boiler Construction Code Published September 20th

For the past ten months the A.S.M.E. Boiler Code Committee has found it necessary to recommend a number of changes and additions to the various sections of the Code. These include: (1) Revision of the Preamble of the Low-Pressure Heating Boiler Code in order to more clearly define the capacity limits of hot-water supply boilers; (2) revision of the classification of welding operators; (3) amplification of stress tables P-7 and U-2 to assign allowable working stresses to SA-213 materials in Grades T7 and T9; (4) revised formulas for bolted flanged connections; (5) provisions for construction of unfired steam boilers in both the power boiler and unfired pressure vessel codes; (6) adoption of working stresses for use with copper, nickel and aluminum materials and their alloys; (7) revisions of 36 existing material specifications and inclusion of six new specifications.

Prices for the 1949 Addenda to each of the following are:

Power Boiler Code	$0.50
Material Specifications	1.25
Locomotive Boiler Code	0.10
Low-Pressure Heating Boiler Code	0.15
Miniature Boiler Code	0.10
Unfired Pressure Vessel Code	0.50
Welding Qualifications	0.10

The 1949 Edition of the Boiler Construction Code is scheduled for publication in November. In its pages will be incorporated the addenda published during 1947 and 1948, as well as those issued in September 1949.

For the complete Code (nine sections and binder) the price is $14.50. For the various sections, when purchased separately, the prices are:

Power Boiler Code, including rules for inspection (2 Sections)	$2.75
Unfired Pressure Vessel Code	2.25
Low-Pressure Heating Boiler Code	1.00
Boiler for Locomotives	1.00
Miniature Boiler Code	0.75
Welding Qualifications	0.90
Material Specifications	5.00
Suggested Rules for Care of Power Boilers	1.25

1950 Unfired Pressure Vessel Code

This new Code, published September 20th and selling for $3.50, is the result of more than ten years' work on the part of the A.S.M.E. Boiler Code Committee. Formulated to meet future requirements, the Code provides rules for the design, fabrication and inspection—during construction—of carbon and low-alloy steel vessels, including: (1) those operating at temperatures below −20° F., (2) vessels fabricated primarily by fusion welding and (3) vessels or parts of vessels fabricated by riveting or by closely fitted bolting.

Appendices give design formulas, supplementary rules for the design of cylindrical shells under external pressure, rules for bolted flange connections and a considerable amount of valuable nonmandatory material—including rules for inspection, repair and allowable pressures for vessels in service.

Some of the important changes of the 1950 Code as compared with the earlier edition are: Clarification of the rules continued from the former code, increased design stresses, completely revised rules for reinforcement of openings, broader inspection rules, capacity certification of pressure-relief devices required, a sliding scale of joint efficiencies for welded pressure vessels, spot examination of welded joints required for vessels designed with the increased unit stresses and provisions for the design of vessels under external pressures at elevated temperatures.

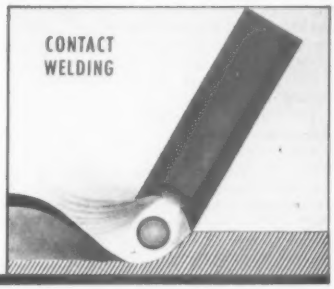
Due to the fact that this new Code does not cover all types of construction and materials permitted by the 1949 Code, vessels may be built to the 1949 Specifications, and also to the 1949 Specifications in combination with provisions of the 1950 Code, except where this conflicts with the 1949 Code.

CUT WELDING COSTS

with NEW type

Norelco

CONTACT WELDING ELECTRODES



● Here is an entirely new type of manual arc welding electrode designed to achieve remarkable results in raising weld quality while lowering welding costs.

Norelco Contact Welding Electrodes make possible lower cost per foot of weld joint, reduced operator fatigue, and higher production rate per unit time.

NOTE THESE ADVANTAGES

1. Deposition rates and welding speeds from 25% to 100% higher than those of conventional type electrodes.
2. Welding made easier by touch-welding in all positions.
3. Not necessary to strike or re-strike the arc.
4. Weld metal of highest physical properties, including high impact strength.
5. Special type of penetration decreases the possibility of undercutting.
6. High deposition efficiencies.
7. More weld metal per pass results in fewer layers; shrinkage and distortion are decreased.
8. Standard welding equipment (transformers, generators, and holders) is used.
9. Very high currents can be used.

Available in two types: Contact 18 (Rutile-Organic coating, AWS E6013 class) for all-position touchwelding, and Contact 20 (Iron-Oxide coating, AWS 6020 class) for extremely fast production welding in horizontal and downhand positions. Both for AC-DC, reverse or straight polarity.

Norelco

CONTACT WELDING ELECTRODES

Send in this coupon for complete technical information and prices.

NORTH AMERICAN PHILIPS COMPANY, INC.
Dept. WJ-11, 100 E. 42nd Street, New York 17, N. Y.

Send complete information and prices on Norelco Contact Welding Electrodes.

Contact 18 ☐ Contact 20 ☐

NAME.....

COMPANY.....

ADDRESS.....

CITY..... STATE .....

Corrosion Service Piping

Taylor Forge Bulletin 485, *Corrosion Service Piping*, is a comprehensive treatment on stainless steel and nickel alloy anticorrosion and anticontamination piping. Economics, standards, advantages of welding, extensive technical data, design tips and complete dimensional information on stainless fittings and flanges are included in the 32-page, profusely illustrated bulletin.

The bulletin is particularly interesting and valuable at this time as the American Standard for Stainless Steel Pipe, A.S.A. B36.19-49, has just been adopted by the American Standards Association. Bulletin 485 was prepared with B36.19 as its basis and it contains a comprehensive discussion and explanation of the importance of this standard.

Hot-Tinning

This booklet, *Hot-Tinning*, by W. E. Hoare, B.Sc (Eng.), F.I.M., A.I.P.E. (112 pp. with 47 illustrations) and published by Tin Research Institute, provides complete working instructions for the production of hot-tinned coatings on fabricated articles and components.

It is essentially a practical manual, compiled primarily to meet the needs of operative tinners, foremen and design engineers. Where theoretical discussion is needed to assist understanding of technique, such discussion is given as simply as possible. Considerable attention is devoted to plant requirements and useful hints on plant layout are provided.

The procedures used for cleaning, pickling and fluxing ferrous and nonferrous metals in preparation for the actual hot-dipping operation are fully dealt with. The composition and characteristics of the various cleaning, pickling and fluxing solutions, and instructions for their preparation and maintenance are given.

The dip-tinning operation in its various forms is described in extensive detail, since this is, of course, the central theme of the work. The sections dealing with the actual dipping processes describe techniques for the coating of steel, cast iron, copper and other metals in both pure tin and in tin-lead alloys and special attention is given to certain new techniques, developed at the Tin Research Institute Laboratories, for the tinning of steel and cast iron.

Methods of minimizing the contamination of tinning baths, for the cleaning and maintenance of the baths and for the disposal of residues are dealt with, and the booklet concludes with a chapter on the examination and testing of hot-dip tinned coatings and an appendix of useful data and conversion factors.

The booklet is so arranged that easy reference can be made to any particular section. It contains an adequate bibliography and is illustrated by numerous diagrams, flow sheets and plant photographs.

This publication is obtainable, free of charge, on application to: Tin Research Institute, Inc., 492 W. Sixth Ave., Columbus 1, Ohio.

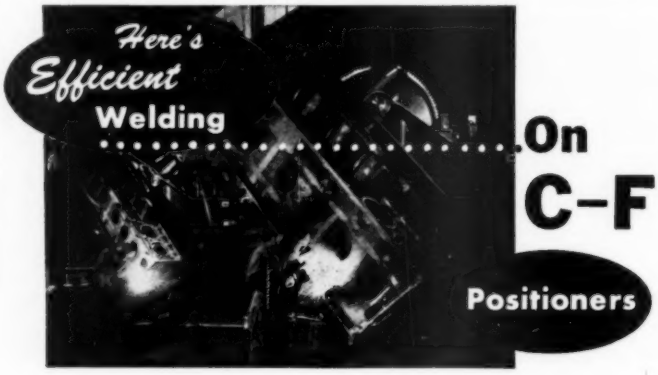
Metallizing Saves Money Rebuilding Worn Packing Areas

The September issue of the *Metco News* reports that users of metallizing are saving time and money on rebuilding worn packing areas. For instance, a steel mill had two 5000-hp. compressors which are used alternately 24 hr. a day, 7 days a week. Due to slight throttle leakage, the stand by unit accumulates moisture at the packing section which corrodes the mild-steel shaft. The corrosive action finally causes them to seize. On one occasion, the rings revolved with the shaft until they were destroyed. Then they decided to try metallizing. Only 11 lb. of high-carbon stainless steel were used on each shaft, and the total machinist's time for one man was only three 8-hr. days. After one year and eight months, the shafts "looked as though they had never been used."

Another user tells of the metallizing jobs they do on heavy-duty press rams. Typical of these is a 7550-lb. ram from a 1500-ton forging press. These iron rams quickly become scored due to their severe service conditions under intense heat and high load stresses, resulting in rapid wear of expensive packing. The rams are now metallized with stainless steel which greatly increases their service life. This user saves over $800 on each repair job, over the cost of a new cast-iron ram.

Another typical metallizing application is the rebuilding of worn pump sleeves. A Canadian paper mill doubled the life of their pump sleeves and saved $900 in labor cost alone.

Write for your copy of the *Metco News*, Vol. 4, No. 10. Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City 1, N. Y.



When heavy, unwieldy weldments like these diesel crank cases can be quickly swung into any position so that every weld is made downhand —that's efficient welding!

Weldors spend more time welding—do better welding at lower cost when they work with C-F Positioners because these hand or power operated machines reduce positioning time to a minimum. Investigate the cost-saving advantages of C-F Positioners. They pay their way in any company

Write for Bulletin WP24, an illustrated circular detailing the specific advantages of C-F Positioners

Cullen-Friestedt Co., 1323 Kilbourn Ave., Chicago

CULLEN-FRIESTEDT CO., CHICAGO 23, ILL.

Technical Drawing

By Grederick E. Giesecke, Alva Mitchell and Henry Cecil Spencer. Published by The Macmillan Co., 60 Fifth Ave., New York, N. Y., price $4.50.

The volume is intended as a class text and reference book in technical drawing. It contains a very large number of problems covering every phase of the subject, and it constitutes a complete teaching unit in itself. The idea has been to illustrate and explain each basic principle from the standpoint of the student, to make it so clear that the student is certain to understand, and to make it interesting enough so that he will read and study on his own initiative. Throughout, the book has been brought into agreement with the latest revision of the American Standard Drawings and Drafting Room Practice (ASA Z14.1), and a complete facsimile of this standard is given in the Appendix.

NEW PRODUCTS

Lighter

The Burdett Oxygen Co., of Cleveland, is now introducing its new Trip-l-ite 3-flint lighter.

This new lighter is made of special tin-coated, flat spring steel designed to retain its shape and maintain elasticity at all times. Correct tension holds flints firmly against file. A new type square cap protects the file from dirt and damage and forms a large pocket for the gas, insuring instantaneous lighting.

A unique feature is the method by which the three flints are mounted on a flat, triangular holder integral with the lighter. Therefore a renewal is available by rotating the flint holder. Trip-l-ite 3-flint lighters are packaged in cardboard cartons. Trip-l-ite flint renewal units are available separately, packaged individually in envelopes.

Descriptive literature and prices may be obtained by writing to Burdett Oxygen Co., 3300 Lakeside Ave., Cleveland, Ohio.

Bronze Electrode

The American Agile Corp. of Cleveland announces another addition to the Agile family of electrodes and welding rods. This is the new Agile Coated Bronze No. 200 Welding and Brazing Rod. It is fully flux coated and is manufactured in 18-in. lengths, 1/8, 3/16 and 1/4 in. diameters. To facilitate easy placement on stock shelves and fast, easy dispensing, it is packaged in the convenient and highly desirable 10-lb. package. The 18-in. length has long been preferred by welders inasmuch as it makes for easy handling and faster brazing.

Complete and uniform metal deposit is assured because Agile coated bronze No. 200 has just the right amount of flux coating on each rod. The flux, with its correct composition and even distribution on each rod, gives an extremely clean weld, free of the vitreous slag that usually surrounds brazed joints when the jointing is done with ordinary bare bronze rod and borax flux.

The new electrode is ideally suited for production brazing and welding. It will increase production brazing (12 to 18%) because this full flux-coated bronze rod eliminates the continuous and tiresome "dipping" of the bare rod into the flux container. By doing away with this "old" method, it is possible to keep dirt out of the flux can thus giving a perfect weld, free of dirt and impurities. The melting point is comparable to most Bronze Rods but in many cases Agile Bronze No. 200 has a lower melting point (1596° F.). This makes for free and fast flowing weld metal. For full information, data and prices write to American Agile Corp., 4806 Hough Ave., Cleveland 3, Ohio.

Welding Rod

This is the first rod, with a copper content above 98%, with which consistently satisfactory welds have been made in fabricating pressure vessels of deoxidized copper. The composition of this rod meets the requirements of designers of equipment for service under corrosive conditions where it is essential that both base metal and weld metal be of high-copper content. An added advantage in the use of this new rod is that with either the oxyacetylene or inert-gas-shielded arc methods, it deposits weld metal, which is sound and ductile, with the full strength of the annealed base metal, and requires no peening or working the welds to develop maximum strength.

To illustrate the use of Anaconda Copper 372 rods for the fabrication of deoxidized copper equipment for processing plants, the Whitlock Mfg. Co., Hartford, Conn., is now fabricating a pressure vessel of deoxidized copper to be shown at the exhibit, using Anaconda Copper 372 rod with the inert-gas-shielded arc method. The tank will be 20 in. in diameter with a shell 36 in. long. The shell is of 1/4-in. thick copper and the heads are 5/16 in. thick. One head will be welded to the shell with a 9-in. port or Vanstone flanged nozzle and a 3/4-in. threaded coupling. The shell will have a 2-in. solid flanged nozzle and a 1-in. threaded coupling. These openings are typical of copper vessels of this design. A backing strip will be tack welded in the other head but the tank will be left open for inspection.

American Brass Co., 25 Broadway, New York 4, N. Y.

Welding Galvanized Surfaces

Eutectic Welding Alloys Corp., New York, announces production of a welding alloy that is particularly adapted for single-carbon arc welding, that can safely weld galvanized surfaces without damage to the coating.

Known as EutecRod 189, it may be used with or without flux to produce distortion-free welds on steel, bronze and copper. For those industries that have problems of welding galvanized surfaces without damaging the coating, EutecRod 189 can be used with assurance. The parts require no preheating, the welding alloy has a high corrosion resistance and there is no danger of destroying the coating while welding, or lowering the corrosion resistance of the finished part.

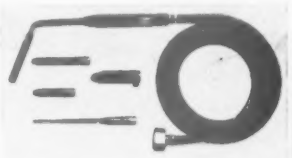
Using EutecRod 189, in size 3/32 in. with single carbon arc, d.-c. machine (it can also be used with oxyacetylene), numerous applications will be found throughout food processing plants, brass and bronze foundries, truck repair shops, thin sheet roofing work and metal shops where galvanized work is done.

The following are recommended amperages and carbon stick sizes, depending on metal thicknesses: with EutecRod 189, size 3/32 in. for 20- to 10-gage metal, use 30–60 amp. and 1/8-in. carbon stick; for 10-gage to 3/16-in. metal use 60–80 amp. and 5/16-in. carbon stick; for 3/16-to 1/4-in. metal use 80–120 amp. and 1/8-in. carbon stick.

EutecRod 189 has close color match to most red and phosphor bronzes and requires little or no preheating for thin parts, though heavy bronze castings should be preheated to about 700° F. It bonds at 1550° F. and has tensile strength of 51,000 psi. This alloy is also available in 1/4, 5/16 and 1/8 in. For further details, write to this company, 40 Worth St., New York 13, N. Y.

Air-Acetylene Outfit

Air Reduction, manufacturers of industrial gases and welding equipment, has announced the immediate availability of the Airco No. 75 Air-Acetylene Outfit for all kinds of small soldering, low-temperature brazing, heating or lead-burning jobs.



The outfit is sold with the following four tips:

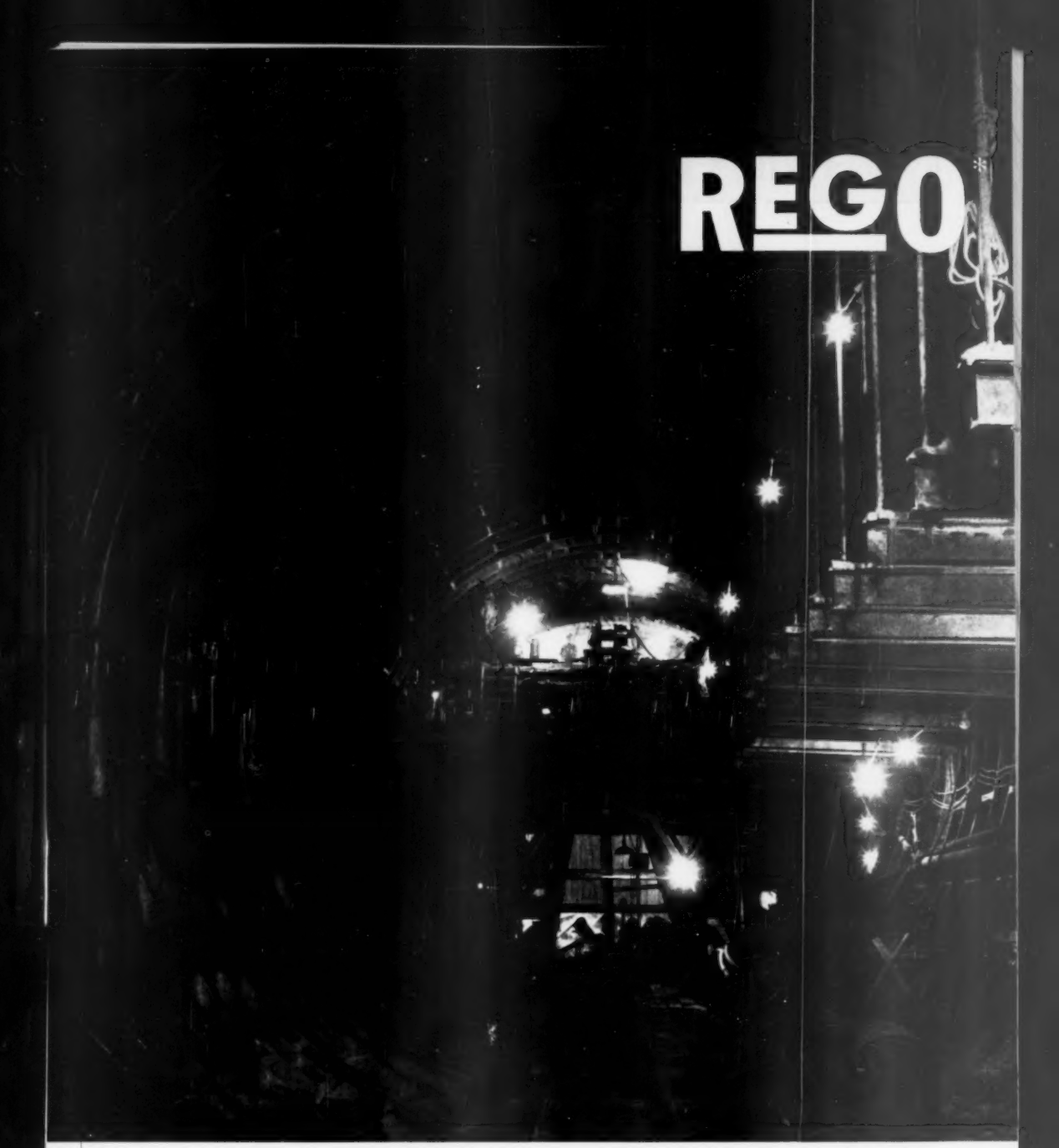
1. Radiator Soldering Tip—slender tubing permits the flame to be used in confined places.
2. No. 9 Tip—when a medium flame is required.
3. No. 10 Tip—produces a pointed flame suitable for concentrated heating.
4. No. 15 Tip—gives a brush-type flame suitable for heating broad areas.

The torch assembly, ruggedly constructed of brass, 5 ft. of 3/16-in. flexible hose, a soldering iron and soldering copper completes the outfit.

Typical uses for the Airco No. 75 Air-Acetylene Outfit are for joining solder-type fitting for copper installations; for soldering hard-to-reach electrical connections and in the repair of radiators and batteries.

New Improved Cable Saddle

This new cable saddle eliminates the hazard of impaired water flow, which causes excessive heat and decreases cable life. Saddle radius permits unrestricted water flow, resulting in additional life to cable. It also eliminates localized bending in cable (previously held by strap), minimizing cable breakage. Movable



NCG oxygen and acetylene were used to tackle one of the most spectacular dismantling jobs in the New York area—the cutting out of four mammoth tunnel shields used in constructing the Triborough Bridge and Tunnel Authority's new Brooklyn-Battery traffic tunnel—the longest under-water highway in this hemisphere—nearly two miles long. Both contractors—Mason & Hanger Co., Inc., New York, and George H. Flinn Corporation, New York—have been users of NCG gases exclusively for many years. The shields, each 31' 8" in diameter and built of 1¼" plates, head up the tunneling operations, providing protection for the miners, who work in front of the shields. The twin traffic tubes from the Manhattan shore, and the two from the Brooklyn shore, met near the ventilation building caisson 125-ft. below New York harbor at a point just north of Governors Island. It took a month of steady cutting to dismantle each of the four shields. NCG portable banks were used to insure reliable flow of gases in ample volume.

Means Dependability

Join the countless others who praise REGO's traditionally high standard of efficiency and accuracy

Where jobs are exacting and call for quality performance, Rego oxy-acetylene welding and cutting apparatus has been *preferred for 30 years*. Behind this old-line name is a record of dependability, efficiency, accuracy and economy—a *combination* that can't be *beat*.

Find out for yourself how Rego can help you *save* gas, turn out *better* work, and *speed* production—as it has for thousands of others in every type of industry you can name. If you'd like an illustrated catalog of *thoroughbred* Rego equipment, write for *Bulletin NR-175*.

NATIONAL CYLINDER GAS COMPANY

Executive Offices:

840 N. Michigan Avenue, Chicago 11, Illinois

Copr. 1949, National Cylinder Gas Co.
*T. M. of The B. B. Co., Chicago

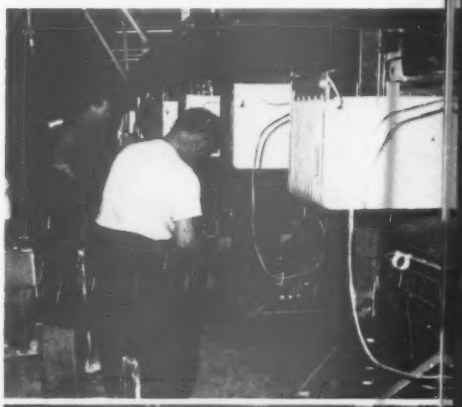
NCG

EVERYTHING FOR WELDING

NCG is recognized as one of the largest organizations of its kind in the world. It operates 73 manufacturing plants within the United States, offers supply and service by a vast network of hundreds of authorized NCG dealers and warehouses. For assured satisfaction in your welding and cutting needs . . .

RELY ON NCG

On the production line at Nash-Kelvinator Corporation's Detroit plant, where Kelvinator refrigerators are assembled, Rego welding torches and NCG oxygen and acetylene are used. Here workers are silver-soldering joints in the copper tubing which carries the chemical refrigerant to complete the refrigerating cycle from the compressor to the evaporator and back to the compressor. The compressor is the black dome-type unit at the base of the assembly.



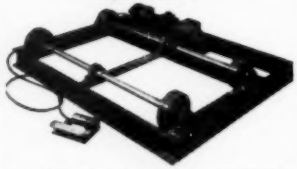
At the Homestead Valve Mfg. Co.'s new No. 3 plant at Coraopolis, Pa., production on "Hypressure Jennys" is kept stepping along with an NCG pipe-line system fed from bulk delivery of NCG oxygen and acetylene. This modern welding set-up puts everything at the workers' fingertips for faster, more economical output. Here are seen the rapid assembling of steam coils for the famous "Jenny" steam cleaning machine, in which both gas and arc welding are used.

TURNING TANKS IS OUR BUSINESS!

YOU'LL WELD 'EM AT LESS COST IF YOU USE

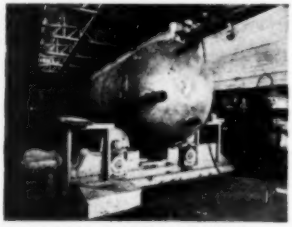
REED *ENGINEERED* **TURNING ROLLS**

THE ONLY COMPLETE LINE OF MODERN TANK WELDING EQUIPMENT



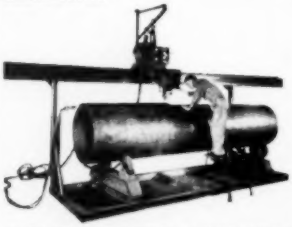
★ **THE NEW RD-20 TURNING ROLL**

Cap. 2,000 lbs.—handles up to 6 ft. × 12 ft. tanks. Priced at $650.00 F.O.B. Factory. Described in Bulletin No. 70.



★ **HEAVY DUTY TURNING ROLLS**

Built in 5 standard sizes — 2 ton, 6 ton, 12½ ton, 25 ton and 50 ton. Complete details shown in Bulletin No. 68.



★ **UNIT TYPE FOR AUTOMATIC WELDING**

Combines Turning Rolls & Track Support into one compact unit. Made in 5 standard sizes—Special units made to order.

★ **POWER DRIVEN PIPE ROLLS**

For accurate fit-up, assembly & welding. Both standard & special units built to your requirements.

We Build a Complete Line of Tank Welding Equipment Including Bending Rolls, Assembly Presses, Horn Jigs, Track Support & Welding Gantries.

COMPLETE INFORMATION MAILED AT YOUR REQUEST

REED ENGINEERING CO.

CARTHAGE, MISSOURI, U. S. A.

cable saddle permits self balancing of gun, thereby giving ease of maneuverability. It is made from strong, light aluminum alloy, with forged steel eye. For more information write Osborn Mfg. Co., Warsaw, Ind.

Jaw Insulators

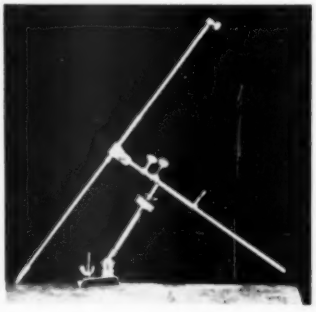
Jackson Products', Warren, Mich., entire line of insulated arc-welding electrode holders is now being furnished with greatly improved jaw insulators at no change in price.

Made of laminated fiberglass with melamine binder and other high heat-resistant material, they are said to be five times stronger than the insulators originally furnished. They retain the familiar channel and crown type design pioneered by this manufacturer.

Illustrated is the Jackson "Featherlight" Model A-W electrode holder showing the new insulators on upper and lower jaws.

Pattern Maker

Reducing day-long jobs to a matter of minutes and eliminating hours of tedious drafting, a pattern making instrument for Sheet Metal Workers and fabricators of piping systems is announced by E. A. Scott, publisher of *Sheet Metal Worker*.



The device permits the average sheet-metal worker or welding operator without engineering training and without resorting to the drafting board, to solve in seconds or minutes most of the pattern problems encountered in sheet-metal work and pipe fitting. It readily marks out cutting openings and other joining lines required to fit round, square, tapered or straight or odd-shaped ducts into round or other-shaped objects, on flat, curved or many-angled sides, on or off center, and at any angle.

This new instrument is called the SMW Pattern Maker, It is available now from E. A. Scott, 45 W. 45th St., New York, N. Y., and sells for $7.50, postpaid.

New Package for Electrodes

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N. Y., announced a new improved standard package for All-State welding rods and electrodes.

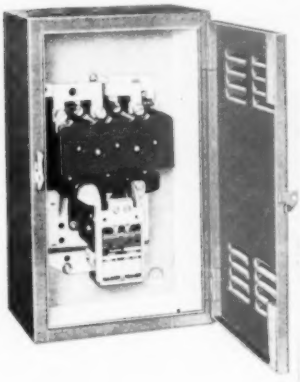
The new package is a metal-capped tube. It replaces all the fiber-board boxes previously used for All-State products.

The particular advantage of tubes All-State has selected over boxes are that they will withstand more and rougher handling and that this durability makes the tube a convenient storage place for rod in the user's supply kit. Attractive design of the tube includes complete instructions for use printed on its outside. The contents are identified on the end for the convenience of the counterman and for his further convenience the tubes provide standard packages of amounts as small as 5 lb. which eliminates the frequent necessity of breaking packages.

50-Amp. Welder Contactor

The new Square D size OW, 50-amp. welder contactor is now in production. It was designed to fill the need for a rugged contactor with long life and high-speed operation for small spot-welding machines up to 10 kva., 220 v. or 20 kva. at 440 v.

High rupturing capacity is assured by



two double-break contacts connected in series, giving a total of four breaks. Heavy copper bus straps allow large welder cables to be easily connected and are conveniently located for accessibility. Silver contacts provide exceptionally long life and never require cleaning or dressing.

A floating armature is pivoted on a hardened steel pin, and the pin bearing is hardened to insure long, trouble-free life. Magnet life has been increased by shortening armature travel and increasing air gap.

Accessibility for inspection and maintenance saves time and labor. Using only a screwdriver, an operator can remove for inspection or replace the movable contact assembly, terminals, contacts and magnet coil.

For further information on the Size OW, 50-amp. contactor, write Square D Co., Industrial Controller Division, Milwaukee 12, Wis.

Production Time of X-Ray Tables a Minimum with Mechanized Cutting

X-ray tables are equipped with rocker arms so that x-ray pictures may be taken in any required position. The table rests and rolls on these arms. Fabrication of rocker arms presents a difficult problem. Rocker arm parts must be cut in the same plane as the top of the table.

By using an Oxweld cutting machine, installed by The Linde Air Products Co., a unit of Union Carbide and Carbon Corp., fabrication problems have been solved at the Baltimore Plant of Westinghouse Electric Corp. In the illustration, both rocker arms are being oxyacetylene cut simultaneously.

The material is mild steel, 1 in. thick. The tracing head automatically follows the templet and the desired shape is duplicated in both workpieces. Note that only a minimum of clamping is needed. No longer is there a problem of correct alignment. Actual cutting takes only a few minutes; the balance of the time is consumed in setting up the work.

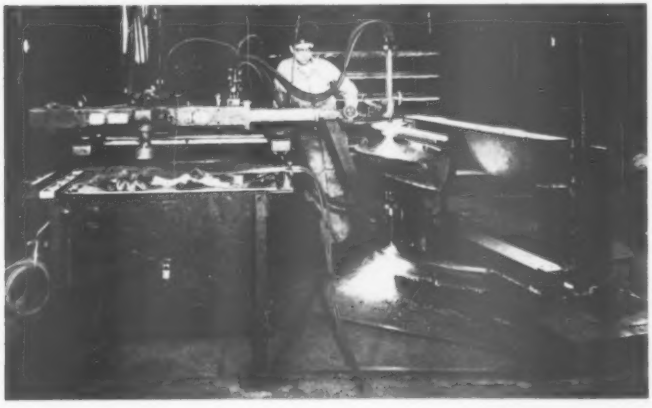
Automatic Spot Welder

Development of a new automatic spot welder, has been announced by the Unitek Corp., located at 697 N. Lake Ave., Pasadena 6, Calif. Named "Unimatic," this new unit introduces "pushbutton spot welding"—press one button, the Unimatic spot welder does the rest. The manufacturer claims the unit actually does your welding thinking for you, as rheostats and other auxiliary adjustments have been eliminated. Designed primarily for use with lightweight stainless steels, the new Unimatic weld shows no evidence of burning, heat distortion, discoloration or splattering.

Unitek engineers, after intensive research, have developed the "automatic" feature by incorporating in the welder a sensitive electronic circuit. When actuated by a touch of the welding button, the electronic brain instantly determines the amount of resistance heat required to homogeneously bond materials through a range of thicknesses. This automatic gaging and simultaneous welding eliminates guesswork on the part of the operator and results in burn-free welds of greater strength.

Unparalleled for its efficiency and time-saving advantages, the Unimatic welder has been designed to meet the exacting requirements of the light materials field.

The Unimatic welder introduces automatic operation at a moderate cost. The unit is sturdily built and compactly designed ($9^1/_2$ x $6^1/_2$ x $4^1/_4$ in.). Operates on 110–120 v. a. c. (50–60 cycle). Special models are available for other current supply. Further information, prices and delivery dates will be forwarded on request.



Get these new facts on Arc Welding to decision-makers in your plant

This easy-to-take 'Pack of Facts' makes the information crystal-clear

Today's arc welding offers the key men in your plant unprecedented opportunities to cut costs... improve quality... lick difficult production problems. Get them the latest facts on this versatile industrial tool *now!*

IT'S EASY—General Electric, as a service to industry, has prepared the facts for you in visual terms that are easy-to-take... linger in the memory.

Here's what the arc welding program offers:

1. A fact-packed manual, describing practical applications of electric arc processes... production feats. *Without sales bias,* it surveys the field *authoritatively.*

2. A full-color, sound motion picture, running thirty minutes, which shows arc welding increasing production and cutting costs in plants like yours.

3. Fully-illustrated highlights booklets, for individual study and review.

Convince yourself first—

We want *you* to be the judge of what these arc welding facts can do. That's why we offer business executives this chance to examine the *Arc Welding Manual* without cost.

Showings Cost You Nothing—With your manual, we'll tell you how to arrange for a FREE SHOWING of the film.

FREE
TO BUSINESS MANAGEMENT

Attach to your business letterhead

General Electric Co.
Section F684-2
Schenectady 5, N. Y.

Please mail me a sample copy of the G-E *Arc Welding Manual* without cost or obligation, with details on how I can arrange for a FREE SHOWING of the film. (Extra copies at regular manual price—$1.25.)

Name_____ Title_____
Company_____
Street_____
City_____

GENERAL ELECTRIC

Electrode Holder

A new insulated arc-welding electrode holder is announced by Jackson Products, Warren, Mich., for those welders who prefer holders of the so-called blade type.

Claimed to be economical, safe and cool working, it consists of a minimum of rugged, simple parts, all easy to replace. Crown-type jaw insulators are said to be as strong and heat-resistant as any ever offered.

Known as Model BT-3 it will take 1/8-in. electrodes at 300 amp. Write for bulletin.

Joining Aluminum

A process expected to revolutionize industrial and job welding of aluminum has been developed by the Air Reduction Sales Co. in research conducted at its Murray Hill, N. J., laboratories and at Battelle Institute, Columbus, Ohio.

The process readily joins aluminum plates 1/8 to 3 in. or more in thickness. It is at least four times faster than any previously known process of welding aluminum which produces welds of equal quality. It requires less skill than present methods of fusion welding of aluminum and is adaptable to semiautomatic and machine operation. No solid fluxes are required, there are no slags to be cleaned from weld joints, and the welder's work is not interrupted to change electrodes. It is the only semiautomatic fusion-welding process known today with which aluminum welds can be made with ease and with little skill in any position—flat, horizontal, vertical or overhead.

The process, termed "Aircomatic," utilizes a pistol-shaped welding tool, through which bare or processed filler metal in wire form is fed at controllable rates of speed. The filler metal carries the welding current and an arc is maintained between the end of the wire and the work. A sheath of argon or helium gas surrounds the arc and prevents air from coming into contact with the molten metal. Power may be supplied from a standard welding generator. The equipment includes both semiautomatic gun and fully automatic equipment.

With the semiautomatic unit, all of the standard joint designs may be welded in every welding position. Pressure on the gun's trigger maintains a closed welding circuit and also a closed circuit in the wire-advancing mechanism. The shielding gas is impinged upon the work through a nozzle which surrounds the wire electrode.

A major problem in all forms of arc welding has been how to keep air away from the molten metal. Air combines with many molten metals forming harmful oxides and nitrides. Resulting chemical and physical actions often produce porosity in the weld and reduce its strength and ductility. In common arc welding, the effects of air are combatted by the use of coated welding electrodes. Under the intense heat of the arc, the coatings form gases which keep air away from molten

Welding aluminum plate in an upright position is easy with this newly developed welding gun

There are no rods to change and the worker "lays his bead" without interruption. The filler metal is fed to the gun automatically from the spool, shown at the right. Argon or helium gas, also fed to the gun, shields the molten aluminum from air and eliminates the need for fluxes, electrode coatings and slag removal. The process will make possible a wide use of aluminum plate in industrial fabrication. It was developed by the Air Reduction Sales Co., in research conducted at its Murray Hill, N. J., laboratories and at Battelle Institute, Columbus, Ohio

SPECIALIZING IN "BETTER-BUILT"

WELDING & SAFETY EQUIPMENT

FOR OVER 25 YEARS

There is a DOCKSON distributor near you. Name on request.

Write for our complete Welding and Safety catalogs.

Dockson CORPORATION

3839 WABASH • DETROIT 8, MICH.

Rectifiers Wanted

Up to 3000 amperes of Rectifiers or motor generator set. Input 220 or 440 volt. 3 phase. 60 cycles. Output 6 volts. Must be in good condition and low priced.

H. S. Boorman
Wall Wire Products Co.
Plymouth, Michigan

metal. Also, slag is formed from the melted coating, which covers the molten weld metal and helps prevent contact with the air. The surface slags are cleaned from the weld after it has been finished. Although coated electrodes work well with many metals, they have their limitations and obvious disadvantages, such as the interruption of work when changing electrodes and the problem of slag removal. Technologists, for many years, have been seeking something better.

The successful development of the Aircomatic process stems from work conducted by Battelle Memorial Institute and Air Reduction Sales Co. engineers for several years on the fundamentals of coated electrodes. Some of the more recent work included a fundamental investigation of the compositions of arc atmospheres generated by welding-electrode coatings. This work demonstrated that arc atmospheres generated by some coatings were inadequate to prevent air from contacting the molten metal. More important, however, this work provided clues to the proper gases for shielding metal-arc welding.

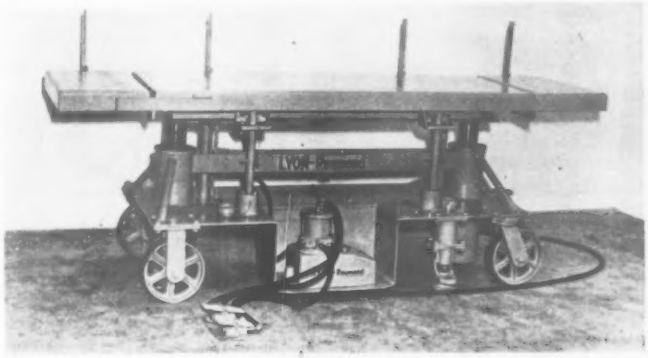
After several blind alleys and months of coordinated effort, scientists of the two laboratories found out why previous attempts to devise a bare electrode process had failed. One by one, various suggested shielding gases were eliminated and the reasons for their ineffectiveness were discovered. Specifications for an efficient shielding nozzle were worked out from the mass of scientific data collected. Perfecting an efficient shielding nozzle involved both studied design and laborious cut and try.

Aircomatic equipment is now undergoing service tests in production work in various parts of the country. The Air Reduction Sales Co. is gearing for the commercial production of the equipment and expects to be able to meet the demand for the welding units as rapidly as industrial plants and job shops find it advisable to adopt them.

Self-Cooled Handle for Soldering Copper

A noncharring, self-cooling wooden handle for soldering coppers is the new development of Unique Mfg. Co., Inc., 226 W. Walton St., Chicago 10, Ill. As the cut-away illustration shows, the air channel inside the handle extends the entire length of the handle, so that the shank does not touch the handle at any point. The freely circulating air makes a perfect insulation.

The shank is held securely in place by piano wire grips in two separate places: one at the head of the handle, and one inside the handle itself. These piano wire grips expand and contract with the expansion and contraction of the shank when heated and cooled, and permit the shank to be slid into the handle as little or as far as desired. Thus, the handle can be held very close to the soldering copper, reducing overhang to a minimum. If the point of the shank extends beyond the heel of the handle, the point can easily be cut off.



Sheet Feeding Table

Manual operation of Lyon-Raymond Hydraulic Elevating Sheet Feeding Tables is eliminated when the company's new air-operated hydraulic pump is installed.

The Lyon-Raymond Hydraulic Pump is now operated by a compressed air motor, thus the table elevates each time the control pedal is pressed down. To lower the table a release pedal allows the oil to flow back into the reservoir.

Loads of steel strips or sheets up to 6000 lb. can be elevated so that the top sheet is always level with the press bed for fast, easy feeding. The table also has a tilt-top arrangement for use with inclined bed presses.

Both the table and the air-hydraulic pump are fully described in literature available from the manufacturer. Write to Lyon-Raymond Corp., 23656 Madison St., Greene, N. Y.

CUTS
PRODUCTION AND MAINTENANCE COSTS MORE THAN HALF

Booth 2531 Metal Show

SPEEDY LAYOUT JOBS ON PIPE AND STRUCTURAL STEEL

NOW! NEW EASE SPEED WITH THE CONTOUR MARKER

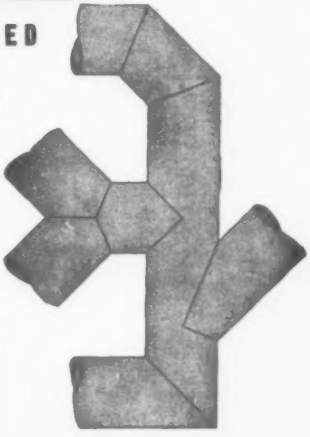
Compact, fits into hip pocket. Efficient, accurate, easy to use. Any of the angles in the illustration to the right can be marked off in five minutes or less on any pipe from 1½ to 18 inches. Save time, labor and gas—will pay for itself in one day.

IF YOUR LOCAL DISTRIBUTOR CANNOT SUPPLY YOU CAN ORDER DIRECT.

TO CONTOUR MARKER CORP.
1843 E. Compton Blvd.
Compton, Calif.

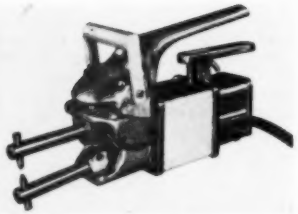
Please send me full details on the Contour Marker

NAME .....
COMPANY .....
STREET .....
CITY .....



Spot Welder

National Cylinder Gas Co., 840 N. Michigan Ave., Chicago 11, Ill., announces the addition to their line of "everything for welding," a new Sureweld Portable Spot Welder which will weld stainless and mild steel up to 1/8 in. combined thickness. It is designed for use in factories, garages, auto-repair shops, sheet-metal shops, on the farm, in truck-body plants, trailer plants, ship yards, home hobby shops, everywhere there is intermittent duty spot welding to be done.



Completely portable it weighs only 23 1/4 lb., operates on 220 v., a.-c. lines (25 amp.), single-phase, 50/60 cycle.

Alternate tongs are available with tips set at 90 or 45° angle, as well as telescopic style which allow maximum reach into hard-to-get-at places.

LIST OF NEW MEMBERS

September 1 to September 30, 1949

ANTHONY WAYNE

Geiser, Jacob S. (C)

ARIZONA

Allison, W. L., Jr. (C)
Binkley, Philip (B)
Brazel, Jesse V. (B)
Carlson, Charles F. (C)
Dutton, Donovan A. (C)
Hadaway, Max F. (C)
Hansen, Allen F. (B)
Hoffman, Ralph A. (B)
Hunt, George D. (B)
Idoine, Harry E. (C)
Ingersoll, F. Johnson (C)
Johnson, Clyde N. (C)
Johnson, J. A. (B)
Kelly, Clyde T. (B)
Klemmer, Larry L. (C)
McDowell, Wendell R. (C)
Mills, William A. (C)
Moore, Edgar M. (C)
Pruitt, Joseph A. (C)
Rader, Paul R. (C)
Rau, J. August (B)
Riley, Walter E. (B)
Ross, George D. (C)
Savage, Hal (B)
Searls, F. E. (C)
Smith, Ralph H. (B)
Sorensen, Neil M. (B)
Stacy, J. F. (C)
Tesmer, A. W. (C)
Townsend, Jack (C)
Willis, Harold (C)

BIRMINGHAM

McCauley, E. D. (B)
Meadors, T. L. (C)

BOSTON

Hackey, Joseph S. (B)

BRIDGEPORT

Bebon, Charles (C)
Kryzanski, Henry (C)

CHATTANOOGA

Kelley, George (C)

CHICAGO

Beedy, H. (A)
Hoffman, David L. (C)
Szymczak, J. F. (C)

CINCINNATI

Davis, B. J. (C)
Fisher, D. H. (C)
Reininger, John H. (C)

CLEVELAND

Munroe, Merle A., Jr. (C)
Zolnowski, Walter J. (C)

COLUMBUS

Mylander, W. C. (C)
Ziegler, Charles W. (C)

DALLAS

Julian, J. F. (C)
Uecker, E. D. (C)
Uhl, T. J., Jr. (C)

DAYTON

Brown, Charles D. (C)

DETROIT

Bartels, Walter (C)
Blakeslee, R. (C)
Berger, Barron D. (B)
Clark, Arthur B. (C)
Crisman, William H. (C)
Eder, Julius (C)
Farrell, Harry (C)
Franz, Frank A. (C)
Hester, H. N. (C)
Mertens, Raymond (C)
Rousseaux, Gordon (C)
Ryder, Orrin J. (C)
Sorensen, Edward N. (C)
Wood, Harry (C)

HOUSTON

Dall, J. J. (C)
Gumm, W. G. (C)
Holmes, Robert D. (C)
Lambright, E. H. (B)
Reitz, Paul F. (C)
Rose, Andrew, Jr. (C)
Stahl, H. Bruce (C)

INDIANA

Block, John W., Jr. (C)

LONG BEACH

Green, C. P. (C)
Hines, James D. (C)

LOS ANGELES

Larza, Francis F. (B)
Mackey, James F., Jr. (B)
Swinehart, Herbert M. (B)

MAHONING VALLEY

Frederick, Charles R. (B)

MARYLAND

Le Grelius, E. L. (C)

MICHIANA

Fetherston, George (C)
Rarick, R. K. (C)

MILWAUKEE

Janda, Frank (C)
Sicotte, James (B)
Smith, Yost T. (C)

NEW JERSEY

Barbarise, John (B)
Diehl, Charles (C)
Hafner, John J. (C)
Hjelm, E. F. (B)
Osha, William (B)
Stanziak, Stephen (C)
Weddinger, Leon Van (B)
Wright, Edward C. (C)

NEW YORK

Clarke, F. T. (B)
Horvitz, Gerald J. (B)
Lemcke, Karl W. (B)
Kubo, Gerald G. (C)
Moles, E. W. (B)
Strate, George J. (C)

NORTHERN NEW YORK

Lospinoso, Samuel (C)
Pagnotta, Gasper (C)

NORTHWEST

Klumb, Kenneth A. (C)

OKLAHOMA CITY

Bainum, Cliff (C)
Johnston, Jimmie (D)

PHILADELPHIA

Ciesla, Joseph A. (B)
Mockus, Dominic C. (C)

ROCHESTER

Egan, Henry (C)
Meisch, John R. (C)

SAGINAW VALLEY

Ferris, R. E. (C)

ST. LOUIS

MacIntyre, R. K. (B)

SAN FRANCISCO

Corlett, Harry B. (C)
Fife, Leland J. (C)
Griaznoff, Serge G. (C)
Neumann, M. R. (C)
Robinson, Charles B. (C)
Valentine, Fred (C)

SYRACUSE

Brown, Clarence R. (C)
Haddock, Robert L. (C)

TULSA

Gearhart, C. F. (B)

WESTERN MICHIGAN

Dephouse, Clyde (B)
Lankenau, Clarence H. (C)

WICHITA

Cummiskey, Edward F. (C)
Scott, R. E. (C)

YORK-CENTRAL PA.

Stock, P. P. (A)

NOT IN SECTIONS

Beckstead, Marvin W. (B)
Byer, Solomon (B)
Christensen, Gordon M. (C)
Christensen, Ralph C. (C)
Clarke, Neil A. (C)
Cuke, N. H. (B)
Drake, A. J. (B)
Jensen, Shirley F. (B)
Kynera, Boris (C)
Lawlyes, Paul P. (B)
Oscarson, George (B)
Roberts, Joseph (B)
Ross, Ralph W. (B)
Sheehan, D. J. (B)
Taylor, Fred M. (C)
Thompson, Stanley E. (D)
Welch, Theodore A. (B)
Worley, Arthur C. (C)

Members Reclassified

During the month of September

CHATTANOOGA

Lorentz, R. E. (C to B)

CHICAGO

Singer, Morse B. (C to B)

CLEVELAND

Smith, Emmett A. (C to B)

HOUSTON

Harrell, W. L. (C to B)

MICHIANA

Grodrian, John (C to B)

PHILADELPHIA

Erlacher, A. John (C to B)
Pierce, Harry W. (B to A)

America's Future Prosperity depends on

Higher Production per Man-Hour

The basis of our well-being has always been closely allied with the *value of goods an hour's work will buy*. As the chart shows, this value has increased from 60c worth of goods in 1900 (at today's prices) to an estimated $1.48 worth in 1950. This value is bound to increase, and smart manufacturers know that *their* prosperity as well as the country's, depends upon their ability to produce more goods per man-hour expended.

here's how one manufacturer boosted production per man-hour eight times!

One of the world's largest producers of wheeled toys was faced with the problem of speeding up assembly of wheels. The assembly involved fastening two stamped wheel halves with 8 spot welds.

Instead of purchasing additional welders, training new operators and taking up valuable floor space, a special *multiple welder* was designed and built by Sciaky. The operator has only to load the gravity feed chute, press starting switch and then keep chute full. Finished wheels drop out the other side at the rate of 30 per minute!

Thus, only one operator welds more than 8 times as many wheels as formerly produced. Here is an instance where skilled use of resistance welding greatly *increased production* and *decreased unit cost*. For a complete description of this machine write for Bulletin No. 25B.

SCIAKY

THREE-PHASE

Sciaky specializes in both a complete line of standard welders, and in the design and manufacture of special units, tailored to your needs. You are invited to consult our Application Department without obligation.

Pioneers and Inventors of THREE-PHASE Resistance Welding Equipment

SCIAKY BROS., Inc. · 4915 WEST 67th ST. · CHICAGO 38, ILL.

SECTION ACTIVITIES

Prepared by C. M. O'Leary

Anthony Wayne

The first regular meeting of the Anthony Wayne Section for the 1949–50 season was in the form of a stag party for members and their guests. The meeting was held at the Orchard Ridge Country Club, Fort Wayne, Ind., from 4:00 P.M. to 12:00 P.M., Thursday, September 15th. Fifty-eight members and guests were present. After golf and horseshoe tournaments, a delicious chicken dinner was served in the club rooms at 7:00 P.M. During the dinner, entertainment was furnished by Nackie McCoy and her accordian.

After dinner, George H. Laws, Chairman; Kenneth Zimmerman, technical representative, and Harry M. Johnson, Secretary-Treasurer, gave short talks relative to the A.W.S., its aims, meaning, advantages, etc.

Cash attendance prizes were then awarded and a session of community singing took place. Those in attendance were then treated to two extraordinary sound-color films showing the history of good preservation, the founding and growth of H. J. Heinz Co. and the history of aluminum, the founding and growth of the Aluminum Company of America.

The balance of the evening was spent in playing cards, visiting and discussions. It was a highly enjoyable evening and everyone liked the idea of starting out the season with a social get-together of this nature.

Arizona

The Arizona Section of the AMERICAN WELDING SOCIETY is finally a reality. Last May Joe Magrath visited with interested people in Phoenix and made the initial plans for the organization. The first organizational meeting was held in June when approximately 35 members were signed up.

Since activity in the Phoenix area is at a low ebb during summer months, the Section confined itself to only one meeting in July, which was a picnic meeting at which the families attended a glorious swimming party. Everyone of the 80 people present enjoyed himself to the fullest.

Charter was granted the first of September and the first technical meeting was held on September 23rd at the Westward Ho Hotel. This was a dinner meeting at which some 45 men were present. After dinner 15 additional men came for the talks. The Section was fortunate in having two very fine members of the SOCIETY from the Los Angeles Section that evening. E. O. Williams, Vice-President of Victor Equipment Co., formerly Chairman of the Los Angeles Section, and before that eight years as Secretary; and Charles Babbitt, Vice-President of Cal Metals Corp., showed up to get the Section off to a flying start.

Mr. Williams gave a short talk on the organizational activities of the Los Angeles Section, which gave the Arizona Section many good ideas on how to conduct meetings. Mr. Babbitt then gave a most interesting talk on his experiences in Europe and the Middle East. Mr. Babbitt also told of his experiences in Germany where he was a member of the American Military Government The commission upon which he worked in Germany studied the welding procedures of the Germans during the Second World War. The information which he brought back has been extremely valuable to our industry.

The meeting closed with a showing of a film on the manufacture of stainless steel. This film was secured for the Section through the efforts of Mr. Aspey of Consolidated Western Steel Co.

The following officers have been elected and are now serving for the year 1949–50: *Chairman*, R. A. Hoffman, Superintendent of Bridges, State of Arizona; *1st Vice-Chairman*, J. Johnson, Central Arizona Light and Power Co.; *2nd Vice-Chairman*, Gus Rau, Allison Steel Co.; *Treasurer*, F. M. Aspey, Consolidated Western Steel Co., and *Secretary*, Allen F. Hansen, Vice-President, Arison Welding Equipment Co.

The following Executive Committee Chairmen are doing an excellent job in their particular field: By-Laws, A. W. Tesmer, Reynolds Metals Corp.; Membership, J. F. Stacy, Arizona Welding Equipment Co.; Hospitality, Gus Waago, Consolidated Welding Supply Co.; Publicity, William Fisher, The Lincoln Electric Co.; Program, Hal Savage, Arizona Welding Equipment Co.; Education, William Geiszl, Director of Vocational Training, Veteran's Administration, Arizona Region; Arrangements, Ralph Smith, The Linde Air Products Co., and Technical Representative, Walter Riley, Allison Steel Co.

Chicago

Regular monthly dinner meeting of the Chicago Section was held on September 16th at Burkes Grill. A magical interpretation "The Lost Weekend" was given by Harold Rygel, Magician.

The technical session was in the nature of a question and answer program with audience participation. The program consisted of an M. C. and three capable judges whose combined knowledge covered the field—one arc, one gas and the other resistance. All three were practical in their knowledge as well as engineers.

Questions were received from the audience with additional questions in the hands of the M. C. to fill in the gaps. The M. C. asked for volunteers to answer the question submitted. The judge indicated the correctness of the answer and the M. C awarded "Dimes" to the person answering. The M. C. decided how many dimes should be awarded. It was previously decided that ten dimes would be the maximum for any answer. If answer was wrong the M. C. could and did fine the party. This phase should be watched and only a token fine such as one dime should be made. The discussions was very lively and the audience reaction was favorable. All phases of welding and allied processes were covered. In a written poll taken at the end of the meeting 95% said it was a good meeting and many requested another.

With the above setup the meeting was both educational as well as entertaining. The Section recommends it as a novel and new audience-participation program.

The following is the program of meetings for the remainder of the season:

NOV. 18, 1949: Inter-Section "Quiz-the-Experts" Contest.

DEC. 16, 1949: "Resistance Welding Applications in Automotive Construction," J. F. Randall, Ford Motor Co.

JAN. 20, 1950: "Carbide and Its Uses," Henry Booth, Shawinigan Products Corp

FEB. 17, 1950: "Design for Welding," L. C. Bibber, Carnegie-Illinois Steel Corp.

MAR. 17, 1950: "Basic Metallurgy of Ferrous and Nonferrous Welding," Dr J. Parks, Armour Research Foundation.

APR. 21, 1950: "Oxyacetylene Equipment, Construction Relative to Safety," E. V. Rupp, The Bastian Blessing Co.

MAY 19, 1950: "Hard Surfacing," T. B. Jefferson, *The Welding Engineer*.

Columbus

Dinner meeting was held on October 6th at the Fort Hayes Hotel. Technical speaker was Wm. J. Phillips, Product Development Dept., Steel Founders Society. Mr. Phillips presented an illustrated talk on "Weldability of Steel Castings." He emphasized the fact that welding and design engineers frequently changed from castings to weldments with very little thought for redesign.

The slides showed several examples where weldments were made to replace castings but were not redesigned. In a good many cases the weldment failed in service because of this disregard for proper design.

The most economical solution seems to be a composite weldment making use of both steel castings and welding. This is especially true where skilled high-priced labor is required to produce intricate shapes or there is great difficulty feeding metal to adjoining parts.

Dallas

The September 21st meeting of the Dallas, Tex., Section was held in the Auditorium of the Mercantile National Bank. Dinner at the Town and Country Restaurant preceded the meeting.

Guest speaker was C. E. Adams, President of the Adams Alloy Co., Waukita, Okla. Mr. Adams presented a clear-cut, interesting talk on "Hard Surfacing for Industrial Tools and Maintenance Applications."

Dayton

"Why, When and How to Stress Relieve Steel Weldments" was the topic discussed by J. R. Stitt of the Mahon Co., Detroit, at the September meeting of the Dayton Section. The meeting was held September 28 at the Dayton Engineers' Club. Using data from his numerous research projects, Mr. Stitt presented definite information on the requirements for stress relieving of welded structures. The effects of welding sequence, holding temperature and rate of cooling upon resultant locked-up stresses and dimensional stability was clearly illustrated. As a conclusion to his address, Mr. Stitt, showed several cases of how shrinkage from localized heating could be used to good advantage in straightening structural members. A lively discussion period followed.

Before the technical session, a sound color movie on "Canadian Tackle Busters" convinced all those present that a fishing trip to Canada was a must for next year's vacation.

A dinner meeting of the Board of Directors was held at Suttmillers Restaurant before the evening session to complete plans for this year's program. Chairman Blankenbuehler announced that Fred Schulmeister asked to be relieved of his board position due to ill health. Charles Allison was chosen to fill the remainder of his term.

Detroit

The Great Lakes Steel Corp. at Ecorse, Mich., was host for the first meeting of the 1949–50 season on September 9th. This plant visitation, with 325 in attendance, was conducted in tour groups of ten men each. The entire trip took two hours. The groups visited the Bessemer converter operation, the open-hearth furnace operation, pouring ingots, soaking pits, slabbing mill, merchant mill, hot strip mill and cold strip mill. The massiveness of the establishment, the order and dispatch with which they carry on their operations, and the size of the material handled from ingot to separate sheets was impressive beyond imagination.

The trip was arranged by Vice-Chairman Keith Sheren, with J. J. Jeffrey, Personnel Director of Great Lakes Steel; and the details were worked out by David M. Moon, Assistant Personnel Director. Mr. Moon directed this trip in an efficient, hospitable manner and the groups moved off without delay. Throughout the trip individual guides added a personal touch by their interesting, explicit explanation of the various processes and machinery.

Included among those attending were two members' guests from London, England, and Lisbon, Portugal.

Houston

Dinner meeting of the Houston Section was held on Thursday, September 22nd, at the Ben Milam Hotel, Houston, Tex. Dinner speaker was H. V. Mosby, Chairman of the Houston Section, who outlined the Section plans for the season. A Gulf Oil Corp. Travelogue Movie was shown previous to the technical meeting.

Speaker at the technical session was C. E. Adams, President of the Adams Alloy Co., Wautika, Okla. Mr. Adams spoke on the subject "Hard Surfacing for Industrial and Maintenance Applications." Discussion followed.

Indiana

Schedule of meetings for the rest of the 1949–50 season is as follows:

Nov. 18, 1949: Meet at Buckley's, Cumberland, Ind., 6:30 P.M. Dinner, speaker and a movie.

Dec. 16, 1949: Xmas Party. Place to be announced, 6:30 P.M. Ladies Night.

Jan. 27, 1950: Meet at Buckley's, Cumberland, Ind., 6:30 P.M. Dinner, speaker and movies.

Feb. 24, 1950: Chevrolet Commercial Body Works, 340 White River Parkway, West Drive, South Indianapolis, 6:30 P.M. Dinner and plant tour.

Mar. 24, 1950: R. C. A. Corp., 501 N. LaSalle St., Indianapolis, 6:30 P.M. Dinner and plant tour.

Apr. 28, 1950: Buckley's, Cumberland, Ind., 6:30 P.M. Dinner, speaker, and pictures.

May 26, 1950: Place to be announced, 6:30 P.M. Election of Officers.

Kansas City

An Inaugural dinner meeting to introduce the new officers to the section to which ladies were invited, was held at the Hotel President on September 9th. O. H. Day spoke on "The Value of Technical Societies to the Individual and Industry."

Lehigh Valley

Comfort A. Adams, the founder and Vice-President of the American Welding Society was the honored guest at the initial meeting of the 1949–50 season of the Lehigh Valley Section, which was held Monday, October 3rd, in the Hotel Bethlehem, Bethlehem, Pa.

J. R. Fairhurst, Vice-Chairman, presided at the meeting. Dr. Adams gave an informal after-dinner talk on "Fundamental Research." He told of the lack of fundamentals in the research work being done in solving our industrial problems.

C. E. Jackson, Research Metallurgist for Union Carbide and Carbon Laboratories, Inc., Niagara Falls, N. Y., was the guest speaker. His subject was "This Thing Called Weldability." Dr. Jackson discussed the methods used to test the weldabilities of steels. He used slides to illustrate data compiled through research programs. His talk was interspersed with feats of magic. Members and guests participated in a discussion period which followed Dr. Jackson's presentation.

Long Beach

The Long Beach, Calif., Section held its first meeting of the 1949–50 season at Miller's Restaurant on Friday, September 16th, where 52 members and guests had a wonderful dinner of fish or steak. As each member or guest entered the dining room he was presented with an A.W.S. Badge, showing his name, affiliation and whether a member or a guest. This was something new for this Section and everyone seemed to like the idea.

The meeting was called to order by the new Chairman, R. Gail Beckstrand, who asked Mal Teeter, Membership Chairman, to name and introduce the new members. The past-chairman, Ray Davenport, was asked to stand and he received a big hand for the fine job he did last year.

First on the program was W. A. Saylor, Chief Metallurgist for Consolidated Western Steel Corp., who gave an excellent talk on "Postwar Review of Welding." Mr. Saylor's address was well received.

Second on the program was R. Hereford, Assistant to the Vice-President of Consolidated Western Steel Corp., who presented a beautiful sound picture in Kodachrome Color of the "Real Discovery of California."

The new officers, Executive Committee and Committee Chairmen are as follows: *Chairman*, R. Gail Beckstrand; *Vice-Chairman*, M. K. McEniry; *Secretary-Treasurer*, Jack Young; *Executive Committee*—M. K. McEniry, Malton Teeter, Chas. L. Breese, Howard Epperheimer, O. B. Bowers, A. J. Smoak, Paul DePietro and Ray Davenport; *Committee Chairmen*—Program, M. K. McEniry; Membership, Malton A. Teeter; Codes, Howard Epperheimer; Ways and Means, A. J. Smoak; Advertising, Paul DePietro; Entertainment, O. B. Bowers and Publicity, Chas. L. Breese.

Los Angeles

Members and guests of the Los Angeles Section responded to the first fall dinner meeting call in "near capacity" numbers. Expertly manipulating the vocal gavel was Chairman Charles Haynes of C. F. Braun & Co. who informally greeted the group and introduced the guests. Vice-Chairman C. T. Schweitzer of Southern California Gas Co. was called upon to present the program which he had arranged.

W. A. Saylor, Chief Metallurgist, Consolidated Western Steel Corp., was the principal speaker. His subject was, "Postwar Review of Welding." A brief statistical summary with a pleasing minimum of numerical details was first given to illustrate the healthy condition of our postwar welding industry. Of special interest was the tremendous increase, through the years, of welding wire tonnage as compared to total ingot production. Continuous increase of welding applications was cited as a natural consequence of economies thereby attained in production. Interestingly reviewed were a select number of recent developments in procedures

and techniques, processes, applications and research.

Presentation of the color sound film "Real Discovery of California," was conducted by its producer and director, R. Hereford, assistant to the vice-president, Consolidated Western Steel Corp. Pictorially told was the story of fabricated steel pipes and their importance in the development of California's water systems for domestic use, irrigation, mining and hydroelectric power. Water brought into farming areas through early riveted and present-day welded well casing and aqueducts was shown to be the "real discovery."

Mr. Hereford was complimented on the professional-like quality of his film production.

Louisville

Lew Gilbert, of Cleveland, Ohio, and Editor of *Industry and Welding*, was the guest speaker at the first fall meeting held on September 27th. He presented a paper on "Check Your Maintenance Welding," which was well illustrated with lantern slides.

Mr. Gilbert followed up his statement that "Welding has become America's principal maintenance tool" with many facts and stories of the welding organizations and the type of work done in a great many industries such as chemical, meat packing, rubber, food, drug, paint, paper, tractor and many other plants. Much emphasis was placed on safety devices and fire protection equipment.

A lively half hour discussion followed the talk and a Dutch lunch was served to close the evening.

Maryland

The Maryland Section started its 1949–50 season with a social gathering in the Maryland tradition, a "Crab Feast," which was attended by approximately one-half the membership of the Section. The feast was preceded by a visit to the Baltimore and Ohio Mt. Claire shops where complete steam and Diesel locomotive repairs are being carried on. Automatic bearing resurfacing equipment, using 95% copper alloy, was demonstrated and welding aids to the general upkeep of the railroad were inspected.

Believing that the SOCIETY has a mission in carrying welding knowledge to wider industrial fields, an effort has been made to expand geographically by establishing a branch in Hagerstown, Md. An initial meeting this summer was attended by 96 people with widely varying welding interests. Hagerstown is essentially a small-shop manufacturing town with the exception of Fairchild Aircraft, which is a relatively large enterprise. The formal incorporation of this branch is expected to be consummated shortly.

Michiana

The Michiana Section opened its 1949–50 season with a demonstration on inert-gas-shielded arc welding, including the new spot welding, at the Wheeler and Hamilton Welding Shops in South Bend, Ind., on September 16th. Frank McGuire Divisional Engineer of The Linde Air Products Co., gave a short description of the processes, then J. M. MacDonald, District Service Engineer, demonstrated. Spot welds were made between thin stainless sheets and stainless to carbon. There was much interest in this new tool for industry.

The hand-torch method was demonstrated on stainless, aluminum and magnesium. This was done very informally with the audience firing questions at the two "Mac's" for over one and one-half hours.

Milwaukee

The first meeting of the 1949–50 season was held on September 23rd. A dinner preceded the meeting with an unusually good attendance.

The technical address was given by Arthur Tesman, Development Engineer of the North American Phillips Co. His subject was "Contact Electrodes and Applications of Contact Welding." Mr. Tesman's talk was well organized and well presented, covering in a comprehensive way the properties of welds made with contact electrodes, the relationship between the current required for contact and ordinary coated electrodes, and the difference between the penetration characteristics of the two types.

A number of questions pertaining to penetration, length of welds, crack sensitivity and ratio of coating on contact electrodes compared with conventional electrodes were answered.

At this meeting the Chairman presented engraved certificates of appreciation to the speakers who presented the educational program last year.

New Jersey

On the beautiful sunny day of Sept. 17, 1949, over 300 members and guests turned out for the New Jersey Section Annual Picnic at the "Pines" in Metuchen, N. J. The activities of the day included golf, baseball, horseshoes, egg throwing, nail driving, golf chipping, paper bag throwing, balloon blowing, rod guessing, three-legged race, beer and sandwich race, and castings contests. Eats and beer were plentiful and good. Many appropriate prizes were distributed. The general consensus was that this picnic was the best ever.

The September meeting was held on September 20th at the Essex House. About 30 were on hand for the dinner and about 85 attended the meeting. Dr. R. D. Stout, Professor of Metallurgy at Lehigh University, talked on "Metallurgy of Welding." Although this was a rather ambitious subject for an evening meeting, still Dr. Stout's clear and concise presentation made it interesting and instructive. The talk produced a lively discussion which extended into the snack period following the meeting.

New York

The New York Section held its first meeting of the season on September 13th when J. H. Humberstone, Director of Apparatus Manufacturing of the Air Reduction Sales Co. and President of Arcrods Corp., spoke before a large audience on the subject "Arc Welding Electrodes."

Inaugurating a new policy, this was the first of a series of dinner meetings to be held by the New York Section at Schwartz's Restaurant, 54 Broad St., New York City. Following dinner, a motion picture, "Television Today," furnished through the courtesy of the Columbia Broadcasting System, was shown and was very well received.

The main event of the evening was Mr. Humberstone's paper on Arc Welding Electrodes in which he discussed many of the problems confronting engineers, operators and governing bodies as to electrode usability characteristics. Mr. Humberstone described the primary functions of an electrode covering, and discussed the factors which determine whether an electrode is usable on alternating or direct current, and those factors influencing the optimum polarity of a d.-c. electrode. The purposes and reasons for the development of the low-hydrogen electrode were fully treated in Mr. Humberstone's interesting talk.

Following the formal presentation of the speaker's paper, the meeting was thrown open and an informal round-table discussion of electrode problems was held. This part of the program in which the audience participated was under the able guidance of J. H. Deppeler, Consulting Engineer New York, who served during the meeting as Technical Chairman.

The meetings for the remainder of the year are as follows:

NOV. 15, 1949: "Designing for Welding," Thomas J. Crawford, Consulting Engineer, Progressive Welder Co.

DEC. 13, 1949: "Hard Facing by Welding," H. S. Avery, Research Metallurgist, American Brake Shoe Co.

JAN. 10, 1950: "Maintaining Weld Quality Through Production and Process Control," Erwin C. Brekelbaum, Executive Chief Engineer, Harnischfeger Corp.

FEB. 14, 1950: Joint Meeting with the Society of Naval Architects and Marine Engineers. "Welding Aluminum," G. O. Hoglund, Engineer, Aluminum Company of America.

MARCH 1950: Joint Meeting with the American Society of Civil Engineers.

APR. 11, 1950: Joint Meeting with the American Society of Metals "Recent Welding Developments Affecting the Metal Industry," G. E. Claussen, Metallurgist, Reid-Avery Co.

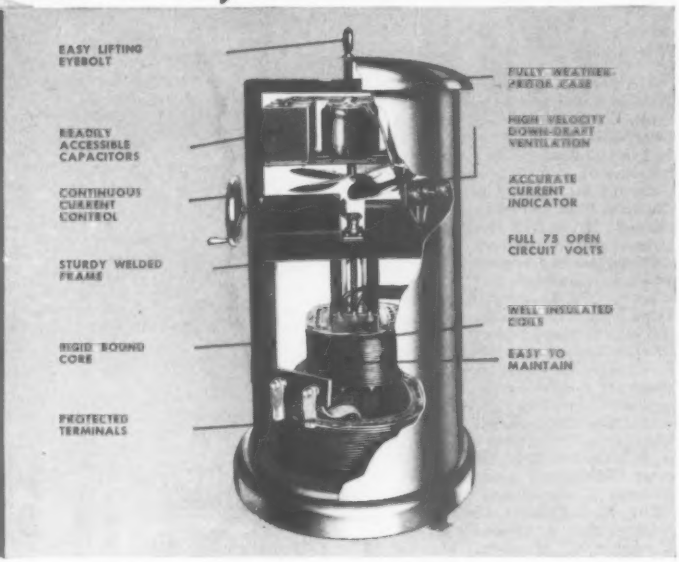
MAY 1950: Annual Social Meeting.

Niagara Frontier

September 22nd meeting was held in the Sheraton Hotel, Buffalo, N. Y. Lew Gilbert, Editor of *Industry and Welding*, was the speaker. His talk "Maintenance and Repair Welding" was presented in excellent fashion and was interesting generally in regard to the size of maintenance and repair operations throughout the country.

PROVED *Every Day on Tough Welding Jobs*

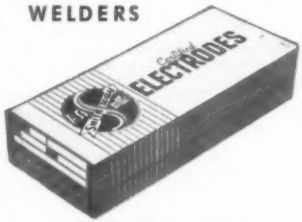
A.O.Smith HEAVY-DUTY AC PRODUCTION WELDERS



A. O. Smith engineers designed this rugged machine for the tough welding jobs encountered in the production of thousands of A. O. Smith steel products. They needed a machine with a fast-starting arc for high-speed welding, and a machine to reduce down-time to a minimum. The result was an AC machine of clean design that produces an easy-to-strike arc, that welds with a stable arc and eliminates arc-blow.

Hundreds of thousands of operating hours every day, on tough welding assignments at our own plants, have proved that the A. O. Smith AC Welder will stand up under service that punishes any other machine. Send the coupon for full details and specifications.

MADE BY WELDERS . . . FOR WELDERS



A.O.Smith *Certified* ELECTRODES

Proved in production in A. O. Smith's own plants—where modern heavy-coated electrodes were originated. Sizes and types for every welding requirement, any welding position, any size job. Send the coupon for our *free* Electrode Catalog.

Electrodes and Accessories Sold by Distributors Everywhere

A.O. Smith Corporation 75th Anniversary 1874 1949

A.O.Smith

AC WELDING MACHINES

New York 17 • Philadelphia 3 • Pittsburgh 19 • Atlanta 3 • Chicago 4 • Tulsa 3
Midland 5, Texas • Dallas 1 • Houston 2 • Seattle 1 • San Francisco 4 • Los Angeles 14
International Division: Milwaukee 1

A.O. SMITH CORPORATION, Dept. WJ-1149, Milwaukee 1, Wisconsin
Without obligation, send us complete information on:

☐ A. O. Smith Heavy-Duty AC Welders ☐ A. O. Smith Power-Saving Plan
☐ A. O. Smith *Certified* Electrode Catalog

Name _____ Firm _____

Street _____ City _____ State _____

Northern New York

Regular monthly meeting of the Northern New York Section was held on September 29th in Schenectady, N. Y. Dr. S. L. Hoyt, of Battelle Memorial Institute, presented an interesting address on "The Weldability of Steels." Films on Fishing Thrills and 1948 Football were shown. A buffet lunch was served.

Northwest

The Northwest Section held its first meeting of the new season on Monday, September 12th, in the Lodge Room of the Covered Wagon in Minneapolis. Meetings this year will be the second Monday in the month.

An opening address of welcome by Chairman H. R. Toll followed a steak dinner and "Happy Half Hour" with Paper, Calmenson & Co. as hosts.

Committee reports covering the coming year's activities were received from the following: Programs, by Dr. F. W. Scott, Vice-Chairman, who outlined the contemplated speakers and subjects; Membership by Co-Chairman Marshall Ford and R. T. Schwabe who have organized two teams for competition in obtaining new members; Questions and Answers, Paul Berry, Chairman; Building and Boiler Codes, E. L. Hixson, Chairman; Acquaintance Committee, T. M. LeVasseur, Chairman; Educational Committee, R. H. Schleuder, Chairman, and Publicity Committee, W. E. Coleman, Chairman.

Dr. Walter J. Breckenridge, of the University of Minnesota Museum of Natural History, spoke on "Minnesota Wild Life" illustrated by colored movies taken by himself. These proved to be extremely interesting to the 67 members in attendance who felt the Section got off to an auspicious start for the new year.

Oklahoma City

September 20th meeting of the Oklahoma City Section was held at The Boardman Company Plant. Dinner was served in the Huckins Hotel Coffee Shop. C. E. Adams presented a clear-cut talk on Hard Surfacing which was well received.

Philadelphia

The Fall Season of the Philadelphia Section started on Monday, September 19th. The enthusiasm and attendance at this meeting indicates an active and full year ahead.

The evening opened with the excellent Coffee Talk by Lt. LeBer, U.S.N., on "The Atomic Bomb" along with the showing of the film on the Atomic Bomb tests at Bikini. The discussion and questions on this interesting and vital subject were stopped only by the necessity of starting the regular meeting.

The welding subject, "Simplified Metallurgy for Welders and Welding Supervisors" by Anton L. Schaeffler, Metallurgical Engineer, Arcos Corp., supplied an interesting and informative evening for the more than 100 members who were out for the first meeting. The speaker discussed the major factors that the designers welders and supervisors should consider when fabricating steels. The subject was divided into three parts to include mild steels, low-alloy; high-strength steels and stainless steels. In the last part was also mentioned the special problem of welding dissimilar metals for which the stainless steel electrodes are so widely used. The understandable language in which this subject was covered and the use of appropriate slides for illustrations insured that each man present left with more knowledge and information on this subject than he previously had.

The fine treatment of this basic welding subject has laid a groundwork which will make the following meetings more valuable.

The evening was completed by the usual refreshments at the back of the room which have done so much to promote the friendly atmosphere for which the Philadelphia Section is noted and to promote the informal discussions and interchange of ideas that prove so valuable to the individual members.

Panel discussions for the year have been arranged for the first Wednesday night of each month.

The meetings for December and January are as follows:

DEC. 7, 1949: "Welding and Fabrication of Aluminum," G. O. Hoglund, Aluminum Company of America.

JAN. 4, 1950: "Welding and Fabrication of Nickel and Nickel Clads," K. M. Spicer, The International Nickel Co., and L. W. Williams, Lukens Steel Co.

Pittsburgh

A plant visitation to the Irwin Works of Carnegie Illinois Steel Corp. at Dravosburg, Pa., held on September 23rd. The plant visit was arranged by F. H. Dill, Chairman of the Program Committee. It consisted of a guided two-hour tour through one of the largest hot and cold sheet mills in the country, including the welding shop. All operations were thoroughly described by competent guides. The plant visit was voted most satisfactory.

Puget Sound

The Puget Sound Section held their opening meeting of the 1949–50 season on Wednesday, September 14th, at the Gowman Hotel in Seattle. It was a dinner meeting and the attendance was 35.

The principal speakers were Jack Price and Howard Cook, both of University Plumbing and Heating Co. which has the heating contract for the new "Grosvenor House" 18-story, 370-apartment building. (Over 285,000 ft. of welded piping is used to heat this building by radiant heat.) Their subject was "Welding as Applied to Piping, with Special Reference to Radiant Heating."

A second feature was a sound film on "Fundamentals of Silver Brazing," by Handy & Harman. John Ross, Field Engineer for Handy and Harman, was present and gave an introductory talk previous to the showing.

Committees for the coming season were announced and the general atmosphere for a successful season was one of optimism.

St. Louis

On September 16th the St. Louis Section made an inspection trip through the Midwest Piping and Supply Co., St. Louis, Mo.

Two hundred and fifty-six members and guests made the trip. Company executive conducted the tour and a wonderful buffet supper was enjoyed after the two-hour trip. A highlight of the tour was the aluminum welding on a new type oxygen plant.

San Francisco

A course in applied welding design, the first of its kind in the Bay area, was opened at Berkeley under the auspices of the University of California Extension. Tom Nicholl, a member of the Section, is conducting the course, which is aimed at engineers who have had little instruction in or experience with welding, expressing the belief that more widespread knowledge of welding design will promote its use. It will deal primarily with structural design.

Guest speaker at the September 26th dinner meeting of the Section was R. J. Lafferty, West Coast Service Engineer for the Handy & Harman Co., who detailed the six important steps in silver brazing: proper fitting, cleaning, support when necessary, fluxing, heating and flux removal. A film "Fundamentals of Silver Brazing" was shown in connection with the address.

The speaker at the dinner meeting was Mr. Miller of the Pacific Telephone and Telegraph Co. A rehearsal of the radio program "The Telephone Hour" with movie film, also took place.

South Texas

At a meeting of the Executive Committee of the South Texas Section held on Sept. 12, 1949, it was unanimously voted to change the name of the Section to the Houston Section of the AMERICAN WELDING SOCIETY.

Western Michigan

The Western Michigan Section, held their first dinner meeting of the season on September 26th at Crackels Grill, Grandville, Mich.

Following the dinner, approximately 80 members and guests assembled to hear Harold Baldwin, Chief Process Engineer of the Peoria, Ill., Division of R. G. LeTourneau, Inc., speak on Welding Procedures.

Mr. Baldwin's talk was divided into three groups: A.-C. Welding vs. D.-C. Welding, Jigs and Fixtures, and Welding of Alloy Steels as applied to their products.

His talk was illustrated with slides made from photographs taken at their plant, all of which were very interesting.

Wichita

A chicken dinner was enjoyed by members present at the September 12th meeting at the Polar Bear Restaurant, Wichita, Kan. Following the short business meeting, an extensive tour was made of Boeing Plant 2 where B47 is under tooling and pro-

Inert Gas Welding with P&H

High-Frequency AC Arc Welders is Better, Faster, and Costs Less

P&H High-Frequency AC Welder Features

- Welds aluminum, stainless steel, magnesium—any hard-to-weld metals.
- Requires no filler metal—no flux, thus no slag.
- No grinding of welds necessary.
- Stable arc.
- Compact design requires little or no floor space.
- No moving parts to cause trouble, delay, or maintenance expense.

1. Dial-lectric control does away with moving coils, cores, sprockets, worms, chains, and levers—for lower maintenance cost and easier operation.

2. Unique high-frequency voltage control brings high frequency into phase easily and quickly — for better cleaning action, faster welding.

3. Rugged construction maintains desired frequency — for smooth, stable performance.

4. P&H's exclusive built-in Dial-lectric remote arc-control feature automatically saves you approximately $100.00.

For best results on inert-gas welding, use P&H high-frequency AC machines. These outstanding welders are available in 150, 200, and 300-amp sizes. Get full details from your P&H representative, or write us for latest literature.

P&H ARC WELDERS
4551 W. National Avenue
Milwaukee, Wisconsin

HARNISCHFEGER CORPORATION

Excavators • Overhead Cranes • Hoists • Arc Welders and Electrodes • Soil Stabilizer • Crawler and Truck Cranes • Diesel Engines • Cane Loaders • Pre-Rose Wire Ropes

duction. Tour was carefully guided and access was given to all operating departments. At the request of the Army authorities the tour was confined to members only. This was an unusually interesting experience and proved an excellent way to start the season.

Worcester

The first monthly meeting of the season was held at the Tower House in Worcester, Mass., on September 28th. The program consisted of a social hour, nontechnical movies, dinner and technical session in which two outstanding speakers presented papers. Seventy-six enthusiastic members greeted the speakers of the evening, G. Richardson, of the General Electric Co., and J. R. Craig, of The Linde Air Products Co.

The title of Mr. Richardson's paper was "Welding of Alloys." He described the types of welding equipment used in the fabrication of jet engines and their numerous subassemblies. Manual arc, inert-gas and controlled atmosphere processes, as applied to the welding of jet engines, were compared.

Difficulties in making satisfactory repairs on structures which had previously been welded by the oxyacetylene process were discussed and emphasized through the showing of micrographs.

A motion picture depicting the progress of Jet Aircraft was shown following Mr. Richardson's lecture.

The second speaker of the evening was J. R. Craig. His paper covered the application of "Powder Cutting of Alloys." The advantages of the process were discussed and the savings in cost over other methods was emphasized. Mr. Craig indicated that the areas cut by the burning operation were adversely affected less from a metallurgical standpoint than they would be from arc welding.

Many interesting applications were shown by lantern slides together with the types of equipment required to do this type of cutting.

Mr. Craig holds the distinction of being the first speaker to be invited to address the Worcester Section a second time. His paper was as enthusiastically received as was his first one on "Heliarc Welding" two years ago.

Current Welding Literature

(*Continued from page 1079*)

40, no. 7 (July), pp. 48–49, 51, 62–64, no. 8 (Aug.), pp. 40, 42–46.

Metals, Hard Facing. Versatility of Oxyacetylene Flame-Hardening Used to Advantage by Commercial Heat Treaters, J. T. Howat. Steel, vol. 125, no. 6 (Aug. 8, 1949), pp. 64–67, 94.

Oil Tanks, Welded Steel. Bulk Oil Storage Tank Construction: Butt Welded Design, L. L. Evans. New Zealand Eng., vol. 4, no. 4 (Apr. 1949), pp. 284–288.

Oxygen Cutting. Flame Shape-Cutting in Railroad Shop Operations, F. B. Rykoskey. Ry. Mech. Engr., vol. 123, no. 5 (May 1949), pp. 253–255; see also Industry & Welding, vol. 22, no. 6 (June 1949), pp. 40–42, 44, 46, 65.

Pipe Joints. Cyclic Heating Test of Main Steam Piping Joints Between Ferritic and Austenitic Steels—Sewaren Generating Station, H. Weisberg. Am. Soc. Mech. Engrs.—Trans., vol. 71, no. 6 (Aug. 1949), pp. 643–649 (discussion), 649–664.

Pipe, Steel, Manufacture. Pipe Production Line. Welding Engr., vol. 34, no. 6 (June 1949), pp. 38–40.

Polishing and Plating Swing Spout Faucets, F. M. Burt. Products Finishing, vol. 13, no. 8 (May 1949), pp. 22–24, 26, 28, 30, 32.

Port Structures, Welded Steel. 200-Ft. Spans Field Welded, H. W. Young. Welding Engr., vol. 34, no. 5, (May 1949), pp. 28–29.

Pressure Vessels. Welding of High-Pressure Air-Vessel Assemblies, K. G. Lewis. Metallurgia, vol. 40, no. 236 (June 1949), pp. 77–87.

Rails, Welding. Flash Welding African Rails, J. M. Lawless. Welding Engr., vol. 34, no. 6 (June 1949), p. 23.

Shipbuilding. New Factors to Be Considered in Design and Welding of Ships, M. Forman. Am. Soc. Naval Engrs.—J. vol. 61, no. 2 (May 1949), pp. 494–505.

Shipbuilding. Ship Welding and Influence of Residual Stress, C. H. Stocks and J. W. G. Thurston. Australasian Engr. (Feb. 1949), pp. 71–74.

Ships, Reconditioning. Thermit Welding Repairs Cracked Stern Frame, M. Ralston. Welding Engr., vol. 34, no. 5 (May 1949), pp. 26–27.

Steam Pipe Lines, Welding. Comparative Cost Data—Screwed vs. Welded Pipe, C. Schott. Nat. Engr., vol. 53, no. 6 (June 1949), pp. 16–17.

Steel Heat Treatment, Oxygas Process. Heating, Forming and Bending by Oxyacetylene Process, W. A. Thiel. Welding J., vol. 28, no. 5 (May 1949), pp. 472–473; see also Industry & Welding, vol. 22, no. 5 (May 1949), pp. 43–45, 73–75.

Tractors, Manufacture. Here's How Caterpillar Does It, C. A. Matheny and W. J. Myers. Industry & Welding, vol. 22, no. 6 (June 1949), pp. 26–29, 64.

Tubes, Manufacture. Tubing Produced by Welding Coiled Strip. Iron Age, vol. 164, no. 4 (July 28, 1949), p. 47.

Tunnels, Railroad, Maintenance and Repair. Longest Tunnel Gets Continuous Rail. Eng. News-Rec., vol. 143, no. 6 (Aug. 11, 1949), pp. 38–39.

Welded Steel Structures. Design, Fabrication and Erection of Welded Building and Hopper Bin, V. A. Murphy. New Zealand Eng., vol. 4, no. 6 (June 1949), pp. 481–490.

Welding Codes. Welding Comes of Age Through Standards, S. A. Greenberg. Standards World, vol. 1, no. 1 (Winter 1948), pp. 37–49; see also Welding J., vol. 28, no. 6 (June 1949), pp. 526–530.

Welding Codes. What's Wrong With Welding Codes? L. K. Stringham. Industry & Welding, vol. 22, no. 6 (June 1949), pp. 32–34, 38, no. 7 (July), pp. 30–32, 34, 36.

Welding Economies Depend On—? S. A. Greenberg. Purchasing, vol. 26, No. 6 (June 1949), pp. 164–165.

Welds. Testing Flash Butt Welds. Iron Age, vol. 164, no. 5 (Aug. 4, 1949), p. 106.

JAN. 16-31
Fight Infantile Paralysis
THE NATIONAL FOUNDATION FOR INFANTILE PARALYSIS
JOIN THE MARCH OF DIMES

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,480,281—Gang Torch Control—Walter Begerow, Wood-Ridge, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

The apparatus of this patent is relatively complicated and it relates to the common control of a gang of gas torches.

2,480,283—Gas Torch—Edwin R. Blahut, Hackensack, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

Blahut's torch has a cutting-oxygen passage which is controlled by a valve and delivers oxygen to the torch tip for discharge. A preheat oxygen passage taps a quantity of oxygen from the cutting-oxygen passage on the upstream side of the cutting-oxygen valve. Fuel gas and the tapped preheat oxygen are mixed to provide a combustible gas mixture which is fed to preheating flames that are projected from the torch tip.

2,480,287—Method for Flame Hardening or Annealing Metal—John J. Crowe, Westfield, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

This flame-hardening process mainly comprises the feature of moving the flames to unit areas of a work surface by alternate relatively long-forward and relatively short-rearward movement of the flames relative to the work surface.

2,480,299—Apparatus for Butt Welding with Induction Heating—Henry O. Klinke, Forest Hills, N. Y., assignor to Air Reduction Co., Inc., a corporation of New York.

The butt-welding unit of this invention includes means for holding the objects with their surfaces to be welded in confronting spaced relation and a housing encloses the adjacent end portions of such objects. An induction coil is slidably supported by the housing for movement to a position intermediate the objects to be welded together and to a position removed from the space between the confronting surfaces of the objects to be welded.

2,480,311—Automatic Welding Apparatus—Joseph M. Tyrner, New York, N. Y., assignor to Air Reduction Co., Inc., a corporation of New York.

Tyrner's new apparatus is of the type wherein a machine carries an electrode and is adapted to feed and advance it along a given line. The machine includes a movable carriage on which the electrode holder is supported and a guide engages the carriage for defining the path of movement thereof. Adjustable pivot means are provided for supporting the guides so that it can be adjusted to give a plurality of laterally inclined positions for the carriage about its pivot axis.

2,480,351—Electrical Resistance Brazing—Carl M. Anderson, Downers Grove, Ill., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

This brazing method comprises the usual steps of positioning the metal parts to be brazed in juxtaposition with brazing material therebetween and a separate sheet of molybdenum is placed over and in contact with one of the parts. The heating means is then applied to such special sheet to conduct heat substantially only through the molybdenum sheet to the parts to braze them and avoid oxidation of the parts.

2,480,376—Welded Tank Construction—Wesley G. Martin, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

A special type of a welded cylindrical tank is covered in this patent.

2,480,635—Apparatus for Electric Welding—John W. Dawson, West Newton, Mass., assignor to Raytheon Mfg. Co., Newton, Mass., a corporation of Delaware.

This electrical system includes special means for connecting a pair of controlled ignition gas-filled discharge rectifier tubes that are connected in a full-wave rectifying circuit between an alternating current supply source and a field winding of a welding generator. The rectifier tubes are alternately connected to the field-winding circuit.

2,480,678—Welding Timer—Arnold M. Skudre, Somerset, Mass., assignor to Raytheon Mfg. Co., a corporation of Delaware.

The patented welding system includes a work circuit with relays for opening and closing such circuit. An electronic timing device is provided and special relays and control are provided for starting the electronic timer and connecting power to the work circuit and a second special relay is operated by the timer to interrupt power to the work circuit.

2,480,863—Welding Apparatus—Howard J. Kerr, Westfield, N. J., Otis R. Carpenter and Frank W. Armstrong, Jr., Barberton, and Nicholas C. Jessen, Akron, Ohio, assignors to The Babcock & Wilcox Co., Rockleigh, N. J., a corporation of New York.

This apparatus is adapted to hold a plurality of workpieces in operative relationship under converging pressures and to burn fuel around such workpieces in the weld zone for preheating the metal in that zone. Resistance welding current is applied to workpieces while the fuel burner is operating and additional means increase the converging pressures on the workpieces during the resistance welding-current application.

2,481,053—Welding or Brazing Flux Composition—Rene Wassermann, New York, N. Y.

This novel flux composition comprises about 25% of cadmium chloride, substantially equal parts of lithium chloride, sodium chloride and potassium chloride together with about 10% of sodium fluoride.

2,481,163—Semiautomatic Welder—Paul H. Sutzler, Hamilton, Ohio.

The welding apparatus of this patent includes a base, a post supported from the base, an electrode holder that is slidably mounted upon the post and adapted to hold a welding rod in engagement with a work surface. Special means are provided for swinging the post and attached electrode abruptly away from the work surface at a predetermined point in the descent of the electrode holder.

2,481,219—Electric Welding—Henry S. Holmes, Arlington, Mass., assignor to Metropolitan Engineering Co., Brooklyn, N. Y., a corporation of New York.

The welding apparatus in this instance has a rotatable center support member and a worktable secured to such member with a plurality of welding heads located on the worktable. A lower support plate is secured to the center support member and a plurality of foot pedals are secured to that plate. One foot pedal is provided for each welding head and the corresponding pedals and heads are operatively connected together and movable as a unit.

2,481,317—Electric Welding Apparatus—Basil Heathcote Lepine-Williams, Coventry, England.

A fixed head for supporting an electrode, and a movable table for supporting a second electrode are disclosed in this patent. Movable clamping means are

provided with the fixed head and the movable table for securing electrodes thereto, while the closing of the clamp and movement of the movable table toward the fixed head is manually controlled. A delay device correlates the movement of the clamping means and separating movement of the table with relation to the electrodes.

2,481,385–2,481,386—Weld and Weld Rod—Frederick Kenneth Bloom, Baltimore, Md., assignor, by mesne assignments, to Armco Steel Corp, a corporation of Ohio.

These patents to Bloom cover a specific type of an electrode and weld produced therefrom wherein specified amounts of chromium, nickel, manganese and iron are present. The maximum percentage of nickel is calculated based upon a special formula using the per cents of other materials present in the electrode material.

2,481,614 — Method of Resistance Welding Aluminum to Steel and Product thereof—Thomas Redmond, Indianapolis, Ind., assignor to Stewart-Warner Corp., Chicago, Ill., a corporation of Virginia.

This resistance-welding method is adapted to join a sheet of stainless steel to a sheet of aluminum. The feature of the invention is that a piece of aluminized steel is resistance welded to each of the sheets of material to be secured together in order to form a unit thereof.

2,481,626—Electric Resistance Welding of Hard to Weld Metals, Particularly for Finned Tubing—Emil A. Schryber, Lynbrook, N. Y.

This welding method relates to "hard-to-weld" metals and includes the steps of introducing a hot-molten layer of lower electrical-conductivity metal between the hard-to-weld metals. Welding current is then passed through the metals while such introduced layer is still in hot condition.

2,481,844—Welding Mechanism—Frederick H. Johnson, Pleasant Ridge, Mich.

Johnson's mechanism includes an electrode positioning means that is adapted to position an electrode in a work-engaging and retracted position. An electrical circuit-controlling means is carried by a positioning means that is adjacent to the electrode-positioning means. Current-conducting means connects the electrodes to the circuit-controlling means.

2,481,952—Welding Electrode Holder—Daniel M. Schwartz, Pittsburgh, and Wm. B. McLean, Coraopolis Heights, Pa.

The novelty of this patent appears to reside in forming a pair of substantially resilient electrode engaging jaws from a copper-beryllium alloy.

2,482,023—Press Welding Machine—Eric J. Opitz, Pleasant Ridge, Mich., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Opitz's patent seemingly is primarily directed to special types of two independent fluid passageways that are provided in a support device and have threaded recesses made in the support and communicating with the passageway therein.

2,482,093—Process for Aluminothermic Welding—Nobel G. Carlson, Cleveland Heights, Ohio, assignor to The Electric RR Improvement Co., Cleveland, Ohio, a corporation of Ohio.

This patent primarily relates to welding a copper bond to a steel rail and includes a step of exothermically reducing copper oxide by means of an aluminum reducing agent to produce a reduced molten metal. This molten metal is discharged into a mold by which the copper bond is held against the steel rail to produce the desired weld.

2,482,209—Welder's Hood—Frank D. Ralston, Seattle, Wash.

The welder's hood of this patent includes a flexible hood with an eyepiece therein. A member is provided within the hood to deflect the breath of the wearer from the eypiece and an aperture is provided in the hood below such deflector member. A peripherally positioned channel member extends around the hood and communicates with the aperture and has an opening therein in the rear of the hood.

2,482,473—Arc Welding Apparatus—Kenneth N. Fromm, Pittsburgh, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

The patented arc-welding system includes an arc circuit and a relaxation oscillator. A pulse generator is provided and is triggered by the oscillator and is connected to apply periodic voltage impulses to the arc circuit.

Employment Service Bulletin

Positions Vacant

V-240. Railroad Service and Sales Representative Wanted. National manufacturer of electrodes and welding rods offers splendid opportunity to organize new department to present its products to railroads. Applicants must have had similar experience and be well known in railroad circles. Thorough experience all welding processes required. Free to travel. Interesting salary, expenses and commission. Rapid advancement if can show results. Give full information on background, references.

V-241. Resistance Welder Sales Engineer Wanted. Excellent opening in Chicago for experienced salesman of resistance welders, to supervise sales of recognized line in Midwest area. Give complete details, experience and background. Remuneration on salary basis.

Services Available

A-583. Metallurgist. B.S. Ch.E. Purdue University. Ten years diversified experience in welding metallurgy research physical testing, heat treatment, quality control. Some experience with high-temperature alloys and aluminum. Steel mill experience. Desires position in development, production or industrial research in northeast U. S. or midwest. Married, 32 years old, one child.

A-584. Supervisor or Chief Instructor. Fifteen years' experience in all phases of welding, burning and fabrication, both shop production and field work. Salary open.

A-585. Metallurgical Engineer desires permanent connection. Received B.S. in Chemical Engineering, 1936. Employed as metallurgist and chief radiographer, Worthington Pump and Machinery Corp. Served in Navy and discharged as Lieutenant Commander, August 1946. Has operated consulting and laboratory service. Past one and a half years served as Asst. Technical Secretary and Assistant Editor, Welding Handbook, to be completed soon.

WELDING METALLURGY

New Edition

Completely Revised to Include all Modern Developments

Copiously Illustrated

Ideal Text & Reference Book for all Engineers

Helps you understand Phenomena in Welding Operations

505 pages - Price $2.50

Order your copy now.

AMERICAN WELDING SOCIETY

33 West 39th Street
New York 18, N. Y.

WELDING RESEARCH COUNCIL

of the Engineering Foundation

Sponsored by the American Welding Society and American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers

Supplement to The Welding Journal, November, 1949

Cracking in Heavy Forged Flanges of Oil Separators

Severe restraint in heavy flanges coupled with steep thermal gradients in the welding of 3-in. forged flanges of gas and oil separators presented a difficult welding problem which was solved by preheating and stress relieving

by H. B. Fergusson and P. L. J. Leder

OUR firm, G. A. Harvey & Co. (London) Ltd., has under construction a considerable number of Gas/Oil Separators, 4 ft. 6 in. inside diameter, for 1500 psi. working pressure, which consist of a number of 25-ft. long units bolted together. Each unit is made from two 3-in. thick cylinders, each made up of 2 rolled belts with a heavy forged flange ring (Fig. 1 (*A*)) welded on at each end. These flanges are 6 ft. 3 in. in diameter overall, and 8¾ in. thick at the bolt circle, and weigh about 3 tons each. The weld preparation is shown in Fig. 1(*B*). The whole of the welding was subject to X-ray examination. No difficulty has been experienced in welding the seams of the rolled belts.

Initial trouble was encountered in welding on the flanges. Cracks appeared in the flanges in the vicinity of the weld. The cracks ran parallel to the circumferential seams a short distance inside the nose of the flange spigot. An immediate investigation was made to ascertain if the trouble was due to the quality of the steel forging, or whether it arose from some other cause such as the extra restraint of the heavy flange.

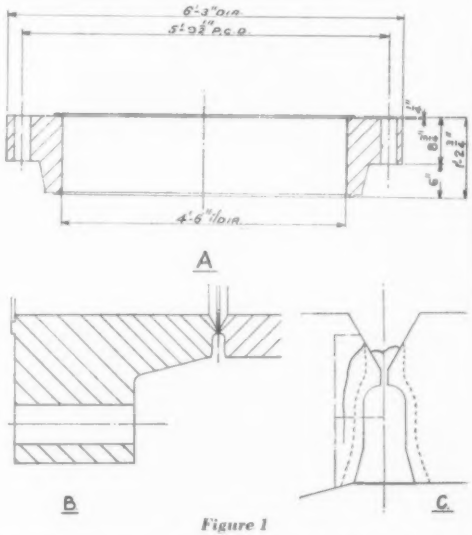


Figure 1

MANUFACTURE AND ANALYSIS OF FORGED FLANGES

Two sizes of ingot were used for the fabrication of the flanges, having gross weights of 91 and 109 tons, respectively. Twenty-five to 30% of the ingot was cropped off the top (removing the whole head and part of the chill) and 5% off the bottom. The cropped ingots were then cogged to 63- and 20-in. diameter holes trepanned at the center. After trepanning, the ingots were cut into cheeses of depth sufficient for two or three flanges, according to circumstances, one ingot making a total of 9 or 10 flanges.

The cheeses were then expanded by forging on a mandrel to the required outside diameter, and then normalized and split into the individual flanges. The

H. B. Fergusson is Director of G. A. Harvey & Co. (London) Ltd., London, England.

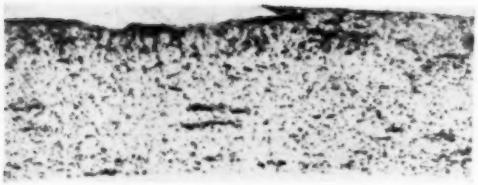


Fig. 2 Sulphur print of Flange No. 29057/A8 (cracked twice). × 1

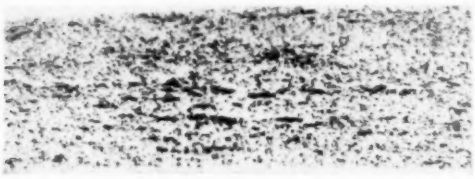


Fig. 3 Sulphur print of Flange No. 29057/A4. × 1

spigots on the flanges were machined out of the solid.

The flanges were made to A.S.T.M. Specification No. 181, Class I, and the following analysis relating to Ring No. 29057/A8, which was the subject of this investigation, is typical: Carbon, 0.23%; silicon, 0.20%; manganese, 0.59%; sulphur, 0.039%; phosphorus, 0.036%; nickel, 0.18%; chromium, 0.14%.

OCCURRENCE OF THE CRACKS

The setup for welding the seam joining the flange spigot to the cylindrical shell is shown in Fig. 1 (*B*), from which it will be seen that the edge preparation consisted of a J on the outside and a vee on the inside. The early welds were not preheated. Welding was begun with a hand run in the vee, followed by several Fusarc machine runs in the outside J. The inside hand weld was then cut out and the vee completed by machine runs. When cracking occurred it usually took place after two or three of these inside runs had been deposited. The cracking, which generally extended over most of the circumference of the seam, was audible but not violent.

As shown in Fig. 1 (*C*), the crack began in the flange side of the vee at a short distance from the edge of the deposit and traveled through the thickness of the nose in a direction at right angles to the axis of the flange. The cracking was always wholly in the nose of the flange and none was ever found on the other side of the weld in the rolled plate.

SULPHUR PRINTING

Flange No. 29057/A8 which cracked twice, and another flange, No. 29057/A4 which was selected at random out of stock, were both surveyed for possible segregation by sulphur printing around the entire circumference of the prepared vee bevel. The results, of which typical sections are shown in Figs. 2 and 3, revealed some small local segregates, but nothing markedly laminated, or which could be regarded as unsatisfactory in a forging of this size. The sulphur content of the steel was confirmed by chemical analysis to be 0.037%.

MACRO- AND MICRO-EXAMINATION OF FLANGE NO. 29057/A8

1. General

The observations made below summarize examinations of micro sections cut from a number of positions around the circumference of the welding nose in the forging which cracked twice, including a part where the crack did not extend.

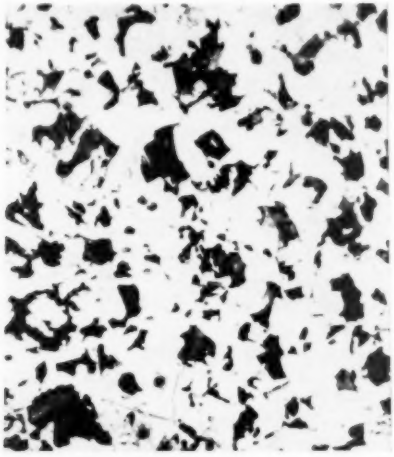


Fig. 4 General normalized structure of forgings. × 94

Fig. 5 "Crazy cracking" near main crack. × 112

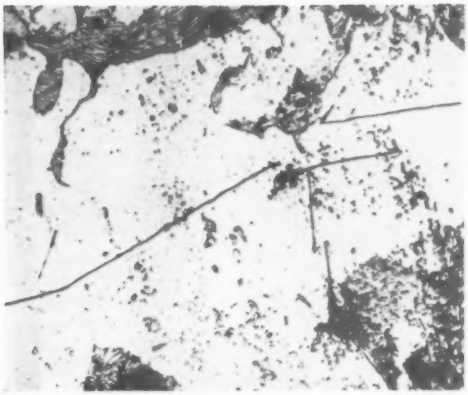


Fig. 6 Fine cleavage cracks extending over several grains. × 625

The forging had a normalized ferrite/pearlite structure, with an A.S.T.M. grain size 4 (Fig. 4). The steel in general was found to be normally clean and free from laminations or segregates. The heat-affected zone of the forging near the weld contained no martensite, and had a maximum Vickers Diamond Hardness of 220. Its structure ranged from a coarse and slightly acicular sorbite/ferrite structure characteristic of the intermediate transition in low-carbon steels, to the normalized structure. There was a somewhat pronounced zone, consisting of a mixture of intermediate transition product and undissolved pearlite grains, due to heating between the critical points. Except at its commencement near the toe of the weld bead, the crack was found to lie up to $^1/_4$ in. outside the heat-affected zone, confirming that the failure was not due to weld hardening. Seen under the microscope the crack was unlike a normal transcrystalline tensile failure in that the main separation had associated with it numerous families of "crazy cracking" (Fig. 5), many of these smaller cracks being sharp and angularly disposed. A further feature of the ramifications of the cracking were the fine "hairline" type cracks shown in Fig. 6.

2. *Special Features*

(*a*) *Cracking on Cleavage Planes.* All the micro-sections showed the presence near the crack of numerous long narrow "plates" of varying sizes (Figs. 7–10), the larger ones having the appearance of very elongated nonmetallic inclusions (Figs. 9 and 10). The possibility that these "plates" were in fact segregates of some kind and that the cracking followed their distribution can, however, be disposed of by the following considerations:

(i) They occurred only in the immediate vicinity of the crack. None at all was ever seen a short distance away from the crack, or in any corresponding part of the circumference of the welding nose, to which the crack had not extended.

(ii) The main direction of the crack was always at right angles to the longitudinal axis of the vessel, and therefore apparently determined principally by the main transverse stress across the weld.

(iii) The "plates" had no general directionality, as would have been the case if they had been due to segregates of some kind in the ingot. They were often inclined at well-defined angles to each other (Fig. 7) and often at right angles to the main direction of the crack.

(iv) If the "plates" were nonmetallic inclusions, their identity and manner of formation would be extremely difficult to explain.

All these considerations lead to the conclusion that the "plates" were the result and not the cause of the cracking, and it is considered that they are almost certainly cracks along the cleavage planes of the lattice (100 planes), which have subsequently become partly or wholly filled with either oxide or possibly polishing material. This would explain their angular distribution and exclusive location near the main fracture. The relationship between these cleavage fractures and the fine cracks shown in Fig. 6 will also be noted.

Fig. 7 Angular occurrence of cleavage cracks. × 625

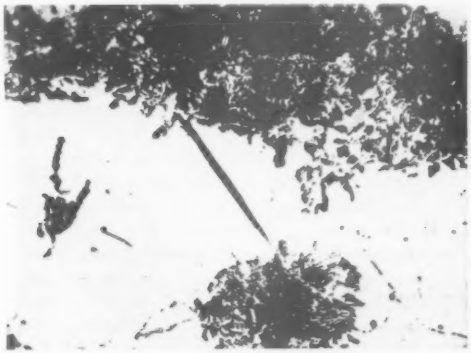


Fig. 8 Typical single cleavage crack extending across one grain. × 625

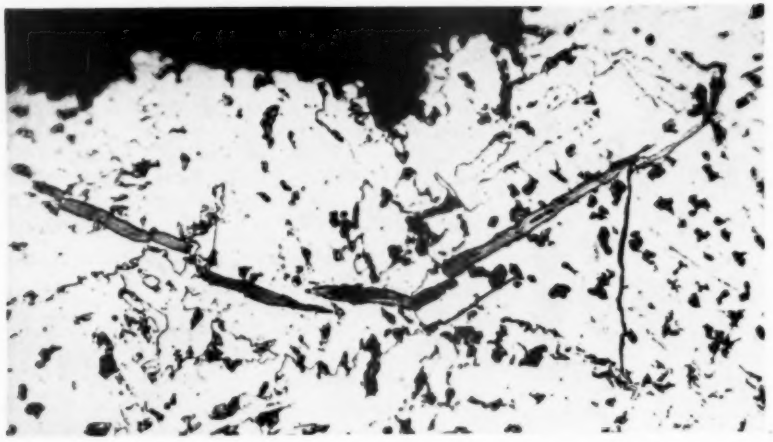


Fig. 9 Coarser cleavage cracks filled with oxide. (Note finer crack at 60° to a coarse crack.) × 625

The presence of cleavage cracks, however, showed that the material was unable to yield by normal slip along slip planes and suggested that the steel may have a somewhat high brittle transition temperature. In order to check this possibility, standard Izod tests were carried out, at 16 and 5°C., respectively, on specimens cut from the nose of the flange. The results were as follows:

		Izod value (ft.-lb.)
16°C.	Specimen No. 1	25
		11
	Specimen No. 2	13
		17
5°C.	Specimen No. 3	7
		6
	Specimen No. 4	8
		11

Two of the results at 16°C. are definitely low, and the scatter between 11 and 25 ft.-lb. is significant. The fact that dropping the testing temperature to 5°C. reduces the impact results to a range of 6–11 ft.-lb. indicates that the up-slope of the brittle transition S-curve probably lies between these temperatures. At 16°C. the material may be approaching the top of the "S" and raising the test temperature to say 25°C. might improve the figures very considerably. This could also explain the effectiveness of the very moderate amount of preheat which has been found to prevent the cracking (see Conclusion 5). The scatter of the results at 16°C. is what one would expect on the steep part of the curve. The broken surfaces of the Izod specimens showed a negligible area of ductile fracture and contained numerous characteristic bright facets, i.e. fractures on cleavage planes. It must be remembered, however, that there is a lot of evidence accumulating at the present time that a hitherto unsuspected number of ordinary commercial carbon steels have brittle transitions at temperatures up to room temperature and even above, and until a complete S-curve has been prepared for this steel, it cannot be certain exactly where the transition lies, or what is its relation to steels in general. It is clear, however, that at 16°C. the impact specimens have all broken with brittle fractures, and that some of the results are unsatisfactorily low.

A number of Neumann lamellae were also seen in the neighborhood of the crack, showing that the steel had not been able to deform in the normal manner. Their presence is decidedly uncommon in a cracked welded structure. Figure 11 shows a typical Neumann band and its relation to a cleavage crack.

The question arises whether, with a material of this kind, the components will be satisfactory in subsequent service, even if uncracked welds are secured. In this connection it is satisfactory to note that tempering at 650°C., as in the stress-relieving operation, is known to displace the brittle transition curve to the left, and

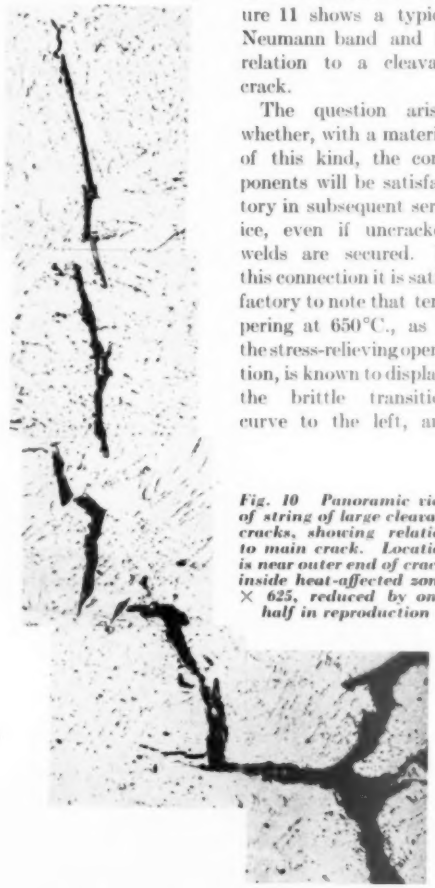


Fig. 10 Panoramic view of string of large cleavage cracks, showing relation to main crack. Location is near outer end of crack, inside heat-affected zone. × 625, reduced by one-half in reproduction

Fig. 11 Neumann lamellae and cleavage crack (angle, 60°). × 625

Fig. 12 Pearlite "feather" and intergranular carbide films. × 625

that satisfactory impact properties in the flanges should therefore be assured.

Some consideration might be given, however, to the possibility of modifying the composition of future forgings of this type. Barr & Honeyman, in two papers presented to the Iron & Steel Institute in October 1947, showed that increasing the carbon content raised the transition temperature, while increasing the manganese content lowered it. From this they demonstrated that there is an optimum manganese/carbon ratio for a given purpose, and in the case of ship plate, for example, they suggested that this ratio should not be less than 3.0 in order to avoid the likelihood of brittle fracture. In the case of the present forged flanges it will be seen that the manganese-carbon ratio is only 2.6.

A further point is the very considerable effect of the rate of cooling after heat treatment on the transition temperature. In a large forging of this kind the cooling rate will be slow, giving a result approaching an anneal, and this may cause quite an appreciable raising of the transition temperature. It is difficult to see, however, what can be done about this, owing to the danger of causing chilling stresses by an accelerated cooling.

(*b*) *Intergranular Carbide Films.* Another feature of interest was first observed in certain lightly etched specimens where the depth of etching was insufficient to bring out the ferrite grain boundaries in the normalized structure of the plate. It was noticed, however, that in the heat-affected areas the ferrite grains were quite clearly defined, although not in continuous networks. Closer inspection of these intermittent grain boundaries revealed the presence of thin films, or sometimes strings of small globules, of carbide between the grains (Figs. 12-14). This feature occurred in those parts of the heat-affected zone which had been heated to an intercritical temperature as judged from the microstructure, and thin feathers of pearlite were frequently seen in the grain boundaries. These feathers were sometimes so thin as to amount to perhaps a single plate of cementite.

The manner in which these films are formed is probably somewhat as follows. It will be remembered that when a carbon steel is passed through or into the critical temperature range, the formation of austenite begins by nucleation at the pearlite/ferrite grain boundaries. As this progresses, carbon from the austenite diffuses into the neighboring ferrite grains which, as they transform from the alpha to the gamma lattice, take the carbon into solution to form fresh grains of austenite. These new grains also nucleate preferentially at the ferrite grain boundaries. If the period in the critical range is short these austenite particles at the grain boundaries will be very small, so that only narrow feathers of pearlite will be formed there on subsequent cooling. Some of these feathers have been observed in the microstructure of the forgings under consideration. If, however, the freshly formed austenite grains are below a certain critical size it is known that they do not form normal laminated pearlite, but instead the ferrite is deposited on the neighboring existing grains of ferrite, while the cementite is left as a single plate or film in the grain boundary. If the thermal cycle in the critical range is spread out by delaying the cooling, then more opportunity is given for the growth of the austenite grains in the ferrite boundaries to a size where they will produce normal pearlite. It follows that the likelihood of these intergranular films being formed will be affected by any factors influencing the rate of austenite nucleation, and hence the number and size of the austenite grains. One important factor in this respect, for example, is the distribution of the deoxidation products which will vary from one steel to another.

An attempt was made in the Laboratory to produce these films by cooling specimens of the steel from 740°C. at varying rates up to a water quench, but no convincing results were obtained. It must be noted that the films were by no means apparent at all points in the original specimens cut from the flange, and it seems that the cooling rate required for their formation is probably critical. The local presence of such intergranular car-

Fig. 13 Pearlite "feather" and intergranular carbide films. × 625

Fig. 14 Films of intergranular carbide. × 625

bides, however, would introduce a weakness which could help to initiate cracking in an already overstressed system. Their effect on the other hand would only be contributory, and must not be over-rated, since it will be remembered that the majority of the crack passed outside the heat-affected region.

Possible Effect of Thermal Aging. Another cause of low impact values in the neighborhood of a weld which must not be forgotten, is thermal aging. It has been shown (unpublished work at I. C. I. Billingham Division) by means of test pieces cut at increasing distances from a weld, that at a given isothermal there is a sudden and marked drop in impact value. This isothermal is approximately in the range 250-300°C., which corresponds to the aging temperature of steel. The position of this isothermal, it will be noted, is outside what is customarily referred to as the "heat-affected zone," i.e., the zone which has a visually modified microstructure.

SUMMARY

1. All the cracks took place in the forged flanges and none has ever occurred in the rolled plate. They passed circumferentially round the seam and traveled from the side of the inner weld at right angles through the nose of the preparation.

2. The forged ring had a normalized ferrite-pearlite structure and was of normal cleanliness and moderate grain size.

3. Sulphur prints showed no undue segregates, and the sulphur content was confirmed at 0.037%.

4. The heat-affected zone contained no martensite and had a maximum hardness of 220 Vickers Diamond Hardness.

5. The crack usually originated near the edge of the heat-affected zone, and then traveled for the majority of its length well outside the heat-affected zone, showing that it was not due to weld hardening. It was abnormal in character containing many subsidiary families of fine cracks on either side of the main separation.

6. Narrow elongated "plates" existing in the microstructure near the weld are believed to be oxidized ruptures on cleavage planes. Izod impact tests at 16 and 5°C. give some indication that the brittle transition range is not as low as would be desirable, but the S-curve would have to be determined more fully to ascertain its relation to other steels.

7. The steel shows a tendency to form intergranular carbide films in the heat-affected zones. These are believed to be caused by rapid cooling from an intercritical temperature, and would be prevented by preheating the flange.

CONCLUSIONS

1. The cracking cannot be traced to any deficiency in the quality of the flange rings in terms of composition, segregates or microstructure.

2. Under complex stress distributions such as in a heavily restrained weld or in the Izod impact test, the steel tends to rupture along cleavage planes and shows a brittle fracture. There is evidence that the brittle transition temperature may be on the high side.

3. The steel also has a tendency to form intergranular carbide films under certain conditions of heating and cooling.

4. The main cause of cracking was probably the severe restraint caused by the heavy flange combined with steep thermal gradients, but the factors in 2 and 3 above may have contributed.

5. Preheating the flange to 100°C. has eliminated the cracking. This additional heat would reduce the effects of all the factors discussed.

6. As the Code requires stress relieving these units at 650°C., it is felt that this will somewhat improve the impact values of the steel forgings.

Fractographic Structures in Weld Metal

The toughness of weld metal deposited from various types of electrodes can be given useful qualitative rating on the basis of the fractographic pattern

by C. A. Zapffe and C. O. Worden

SUMMARY

FRACTOGRAPHY is applied to the fractures of mild-steel weld beads from several types of electrode for purposes of (1) determining the general nature of the cleavage patterns of weld metal, (2) comparing the toughness of the various deposits on the basis of fractographic pattern, (3) studying certain effects of hydrogen from cellulosic electrodes and improperly dried E6015 electrodes and (4) observing special structures which may exist, particularly in high-phosphorous deposits.

An expected sensitivity of the fractographic pattern is found, the phosphorized metal being readily identified, and the other deposits at least showing qualitative distinctions. A possibly new observation is also made of intragranular gassiness, having the nature of the "fisheye" phenomenon on an extremely fine scale.

INTRODUCTION

Recent successful application of the microscope technique "fractography"[1] to cleavage facets in steel[2, 3] invites a study of weld fractures, particularly because cleavage characteristics have been at least tentatively identified both for "toughness"[2-4] and for hydrogen embrittlement.[2, 5] The former, toughness, is always a critical issue in welding; and the latter, hydrogen, has become the focus of much attention through the work associating hydrogen absorption with weld failures[6-8] and the wartime development of the "low-hydrogen" welding electrode.

Consequently, we have chosen to examine a series of fractured welds made with various common electrodes, and particularly with respect to the comparison in fracture characteristics which might be afforded between welds made under conditions of varying hydrogenizing propensity.

C. A. Zapffe and **C. O. Worden** are Consultants, Baltimore, Md.

This paper is from work conducted in the laboratory of the senior author under sponsorship of the Office of Naval Research. Presented at the Western Metals Congress, A.S.M., Los Angeles, Calif., Apr. 11-15, 1949.

MATERIALS AND METHODS

Through the courtesy of Dr. G. E. Claussen and the Reid-Avery Co., several groups of fillet-welded tee joints were prepared from $^1/_4$-in., hot-rolled mild-steel plate. Each right-angle fillet was made with a single bead, using $^5/_{32}$-in. electrodes and direct current. The welds were cooled in running water 15 sec. after completing. Specimens were sawed under water from the middle third of each weld, except where otherwise noted, and were fractured by hammer-blow either at room temperature or at the temperature of liquid nitrogen (−196° C.), as will be discussed. The samples are described in Table 1.

Some comment is probably in order with regard to this manner of fracturing, by hammer-blow, because of the great attention being paid today to the effects of stress characteristics on fracture type, and the common belief

Table 1—Description of Specimens*

Specimen No.	*Electrode type*	*Amp.*	*Polarity*	*Remarks*
1	E6010	145	Reverse	No special treatment
2	E6015	160	Reverse	Electrode dried 1 hr. at only 300° F.
3	E6015	160	Reverse	Electrode dried 1 hr. at 800° F. and subquently shorted (≈800-1000° F.) 10 min. before welding
4	E6015 Special†	160	Reverse	Electrode dried 1 hr. at 600° F. Weld deposit contains 0.39% phosphorus
5	E6020	150	Straight	No special treatment
6	E6015	160	Reverse	Electrode dried 1 hr. at 600° F.
7-1	E6015	160	Reverse	Electrode dried 1 hr. at 300° F. only. Specimen from first $^1/_2$ in. of fillet (first $1^1/_2$ in. of electrode)
7-2	E6015	160	Reverse	Same, but specimen cut from second $^1/_2$ in.
7-3	E6015	160	Reverse	Same, but specimen cut from last $1^1/_2$ in. (crater excepted)
8	E6012	140	Straight	No special treatment

* $^1/_4$-in., hot-rolled, mild-steel plates welded at right angles with a single bead in the fillet from a $^5/_{32}$-in. electrode, d.-c. current. Specimens cut from middle third of bead, except 7-1, -2, -3, as noted.

† E6015 plus phosphorus to provide 0.39% P in the weld metal.

that the conditions of fracture must be carefully controlled if data on fractures are to be comparable.

Since the nature and significance of the fractographic patterns are being discussed at length in separate communications, the authors will only state here that the basic patterns are believed to be intrinsic to the grain, and largely expressive of intragranular imperfection deriving from the liquid state, and that any fracture condition which opens the grain reveals this basic pattern. Embrittling factors such as low temperature and high rate of force application favor cleavage without interference from slip; and those factors can force ductile metal to fracture in a brittle manner. But, once the grain cleaves, it reveals that basic architecture which underwrites its entire behavior and, perhaps more important, provides an individuality to the particular composition under consideration. The principal point in work of the present type therefore is to get the metal to cleave.

If there is an effect of either temperature or fracture condition on the pattern of a given cleavage family within a given specimen [e.g., cleavage on (001) planes], it is much less important in micro-fracture traverses than one might predict from studies of macro-fracture characteristics.

Nevertheless, comparisons will be restricted to fractures of a given temperature, with exceptions noted. As the following patterns show, the fractographic story is both consistent and reproducible using the simple methods described.

However, because of the variability of weld metal and the sensitivity of the fractograph, not one pattern, but a moderate range of patterns is usually found on a thorough exploration of weld fractures. Evaluation of the welds in the present study was therefore made by securing a group of 5 or 10 fractographs for each specimen and, in addition, by obtaining a qualitative statistical rating for each pattern on the basis of a visual exploration of a great many more facets. The welds were then rated. In the following figures, two fractographs are often selected from each specimen-group to represent the characteristic or predominating pattern by their similarities, and the range of the patterns by their differences.

FRACTOGRAPHIC STRUCTURES

Cellulosic Type, E6010 Electrodes

In Fig. 1 there appears a typical cleavage facet for the welds made with the cellulosic Type E6010 electrode. The low-temperature impact resistance of welds made from these electrodes is known to be generally inferior,[9] presumably because of the availability of hydrogen from the decomposing coating; and the facets are expectedly expansive and flat, visually indicating rather ready cleavage—hence inferior "toughness."[2-4] The facet represents a single grain, and perhaps the entire grain, for the specimen was fractured at the temperature of liquid nitrogen (−196° C.) where interruption of a cleavage traverse by interfering slip movements is virtually precluded.

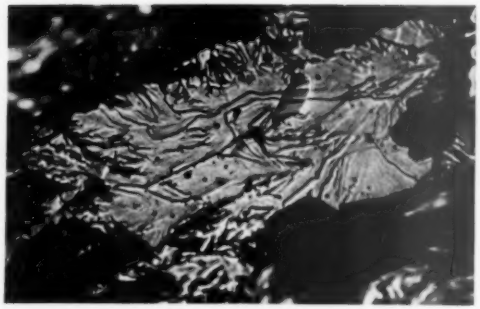


Fig. 1 Typical cleavage facet in weld metal from E6010 cellulosic electrode fractured at −196° C.

The relatively expansive and flat facet shows this metal to lack in "toughness." Specimen 1. 800 ×. (Reduced 1/3 in reproduction)

In Fig. 2 a new observation is made—intragranular gas holes. The shining wall inside the cavity is consistent with the belief that this is a hydrogen bubble; and it may also be significant that the surrounding pattern is especially flat, indicating less toughness, and perhaps also relating to hydrogen embrittlement localized about the gas pocket. If this is true—and it conforms exactly to the hydrogen hypothesis for "fisheye" formation[6]—then this is probably a new observation of that phenomenon operating on a scale much more minute than commonly discussed.

A further facet developed by fracture at −196° C. is shown in Fig. 3 because of the additional evidence of gassiness on an extremely fine scale—"intragranular gassiness," it might be called, for it is believed to be somewhat distinct from commonly observed porosity, both in size and location.

"Hydrogen-Free," Type E6015 Electrodes

Immediately, one's interest is aroused in the comparison of types 6010 and 6015 electrodes on the basis of fracture pattern because of the alleged differences in hydrogenizing propensity. A series of specimens was

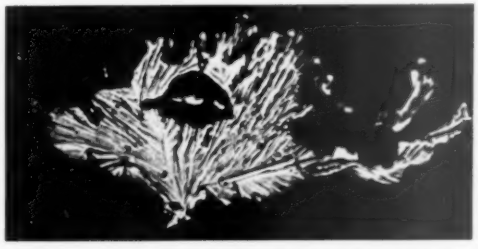


Fig. 2 Cleavage facet in weld metal from E6010 cellulosic electrode fractured at room temperature

Note the gas-hole and the specially flat cleavage traverse of the surrounding grain. Specimen 1. 800 ×. (Reduced 1/3 in reproduction)

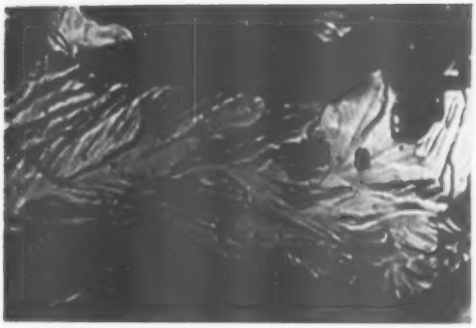


Fig. 3 Typical cleavage facet in weld metal from E6010 cellulosic electrode showing intragranular gassiness

This shows porosity on a fine scale within the grain and is more or less a characteristic of E6010 weld metal. Specimen 1. 1200 ×. (Reduced 1/3 in reproduction)

accordingly run with metal deposited from E6015 electrodes, and under conditions of varying dehydration of the electrode.

In Fig. 4, a fractograph of Type E6015 weld metal made from electrodes improperly dried at only 300° F. certainly shows no improvement over those just examined.

In Fig. 5, two more fractographs of the same material show an interesting pattern not observed in the preceding specimens. These are believed to be patterns of the actual crystal growth, which explains their involved dendritic nature. The presence of these peculiar patterns should not be construed as a variability of fractography, the authors believe on the basis of other work, but as an actual variation in grain structure and/or composition in keeping with the known variability of weld metal.

Referring back to Table 1, one will observe that the fractographs in Figs. 4 and 5 were obtained from metal in the first 1/2-in. of the bead. Since the welding heat might dehydrate the coating to some extent, facets from later deposits should be compared. In Fig. 6, metal from the second 1/2 in. of bead is shown. The upper fractograph is quite comparable in flatness with that in Fig. 4, and is more expansive; but the lower fractograph now gives evidence of definite toughness.[4] Some grains in the deposit, therefore, are developing a resistance to cleavage, though the effect is still sporadic. The upper fractograph in Fig. 6, incidentally, shows several crystallographic markings traversing the whole field and indicating that a single grain is being observed and that some plastic movement had initiated.

In Fig. 7, the bead-section from the last portion of the electrode is being examined. Here the pattern of toughness is much more in evidence, as one can observe by comparing these fractographs with those from the E6010 electrode in Fig. 1. A gradually improved toughness during the course of the consumption of the electrode is also evident from a comparison of Figs. 4, 6 and 7. This does not necessarily mean that the mechanical properties become markedly improved from front-to-rear of a bead laid from an improperly dried electrode, but it does mean that the toughness improves sufficiently to be detected in the fractographic pattern. Perhaps studies of the slip-transition temperature would disclose this trend as a lowering transition temperature as the electrode burned down; but these were not made.

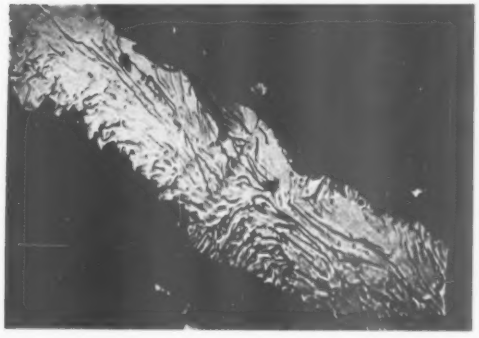


Fig. 4 Cleavage facet in weld metal from E6015 electrode dried at 300° F. before welding

This fractograph is from the first 1/2 in. of the bead and indicates little improvement over the condition shown in Fig. 1. Specimen 7-1. Fractured at −196° C. 600 ×. (Reduced 1/2 in reproduction)

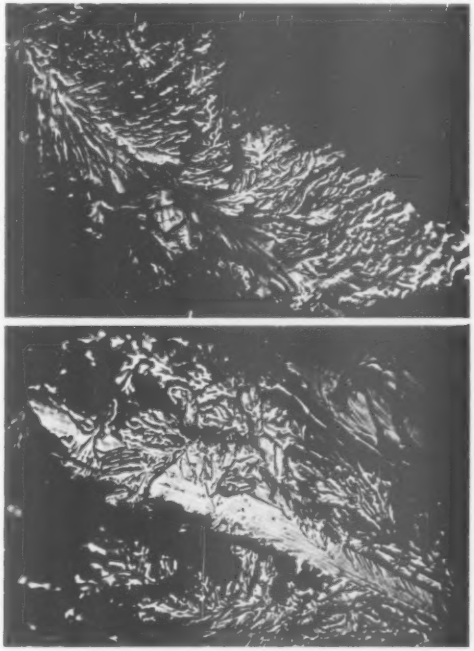


Fig. 5 Same metal as in preceding figure, but showing peculiar dendritic forms

Specimen 7-1. Fractured at −196° C. 600 ×. (Reduced 1/2 in reproduction)

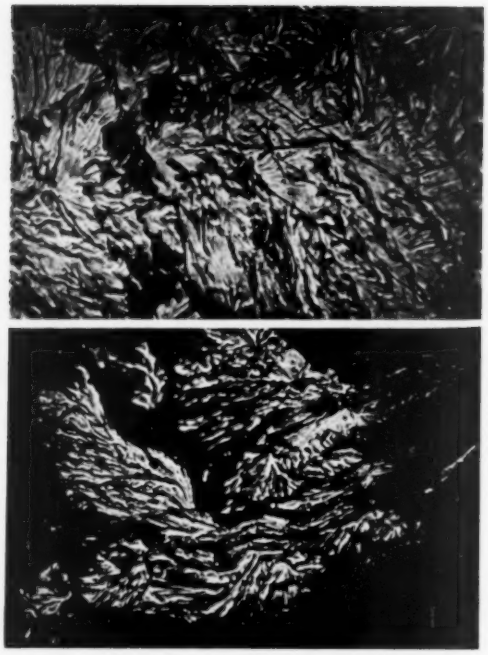


Fig. 6 Cleavage facets from second 1/2 in. of bead in Fig. 4

A marked improvement in toughness is indicated in the lower fractograph, though little in the upper. Specimen 7-2. Fractured at −196° C. 800 ×. (Reduced 1/2 in reproduction)

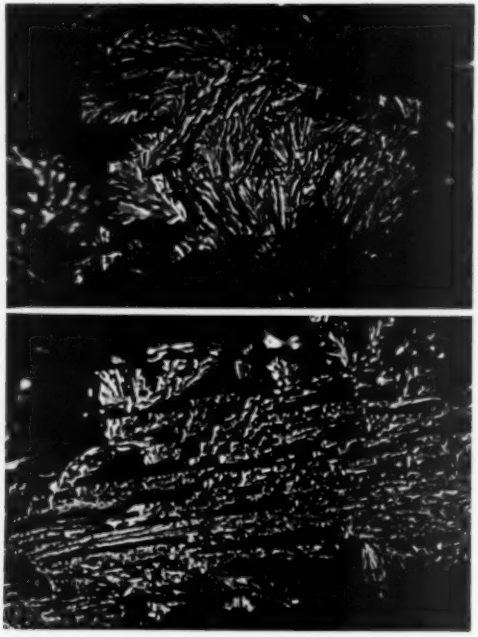


Fig. 7 Cleavage facets from last section of bead in Fig. 4

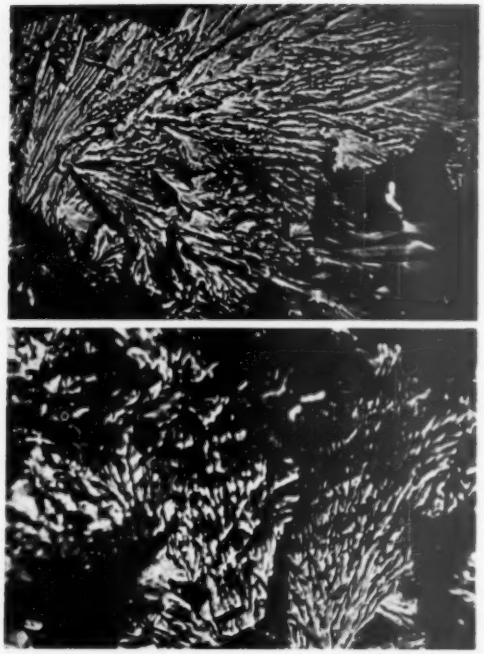


Fig. 8 Cleavage facets in weld metal made from E6015 electrode first dried 1 hr. at 600° F.

These compare closely with those in Fig. 7. The most brittle facet shown in the upper fractograph is considerably rougher than that in Fig. 1; and the lower fractograph is typical of numerous facets too rugged to photograph clearly. Specimen 6. Fractured at −196° C. 800 ×. (Reduced 1/2 in reproduction)

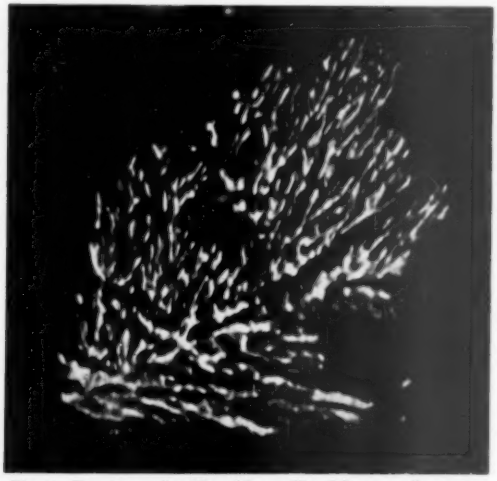


Fig. 9 Fractograph of bead from Fig. 8 fractured at room temperature

The toughness of this metal is especially apparent as compared to the pattern in Fig. 2. Specimen 6. 800 ×

(Fig. 7) Left

The benefit of the dehydration of the electrode by welding heat is now much more in evidence, both facets indicating improved toughness over preceding specimens. Specimen 7-3. Fractured at −196° C. 800 ×. (Reduced 1/2 in reproduction)

To compare a normal predrying technique for this electrode with the foregoing series, welds were made with electrodes first dried for 1 hr. at 600° F. The patterns in Fig. 8, for metal fractured at −196° F., are comparable perhaps to those in Fig. 7, the upper fractograph showing a grain typical of the most brittle ones found and being considerably rougher than that shown in Fig. 1; and the lower fractograph being typical of numerous grains whose cleavage traverse is so rough that photography is difficult.

Perhaps the value of the "hydrogen-free" electrode is better brought out in Fig. 9 where a bead from an E6015 electrode dried at 600° F. for 1 hr. is fractured at room temperature. Comparing this fractograph with that in Fig. 2, also representing fracture at room temperature, provides rather marked evidence for greater toughness in the 6015 bead. This is consistent with the work of Bunn,[10] who found the slip-transition temperature for 6015 weld metal to be lower than that for other electrodes.

In closing the discussion of E6015 fractures, one more test is reported in the following two figures. These are from Specimen 3, which was prepared from E6015 electrode given a drying treatment at 800° F. for 1 hr., and then in addition 10-min. before welding the rods were short-circuited to insure maximum dehydration.

Accordingly one is not surprised to find facets of uniformly tough appearance in Fig. 10, a typical facet on the brittle side being shown above, and one on the tough side below.

In Fig. 11 two fractographs of this same material are presented because their pattern represents a departure in type. The principal difference seems to lie in the fact that a great number of separately nucleated structures appear in each field, in contrast to previous patterns which show lineage-like structures generally deriving from one nucleus, typified by Fig. 9. Each "fan" is believed to relate to a separate lineage or subgrain; and one may tentatively make the broad statement that the lineage structure of the metal in Fig. 11 differs from preceding structures. The patterns, along with those in Fig. 5, are to be classed as unusual, their special significance, if any, remaining to be explained.

Type E6012 Electrodes

In Fig. 12, typical fractographs show the cleavage pattern of weld metal deposited from 6012 electrode. This electrode is generally believed to be inferior with respect to mechanical properties of the weld deposit; and one is not surprised therefore to observe the immense and flat cleavage traverses shown in the figure. The magnification has been necessarily reduced 60% to

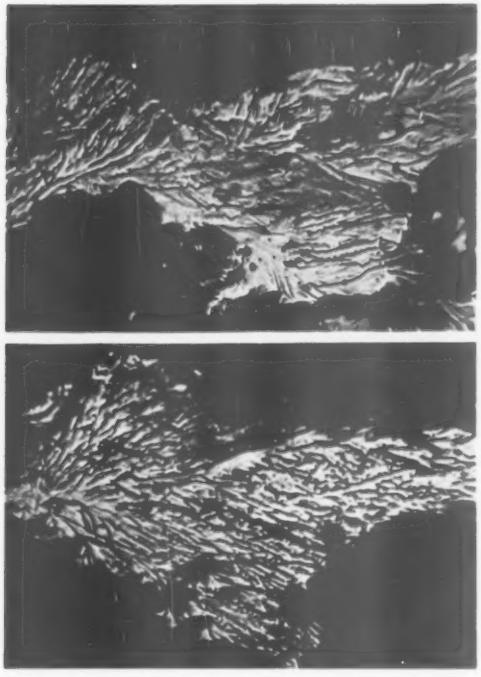


Fig. 10 Cleavage facets in weld metal from 6015 electrode dried at 800° F. 1 hr. and further dehydrated by short circuiting 10 min. before welding

These patterns compare closely with those in Figs. 7 and 8, the upper typing the most brittle facets found. Possibly a slight improvement results from the added heat treatment. Specimen 3. 800 ×. (Reduced ½ in reproduction)

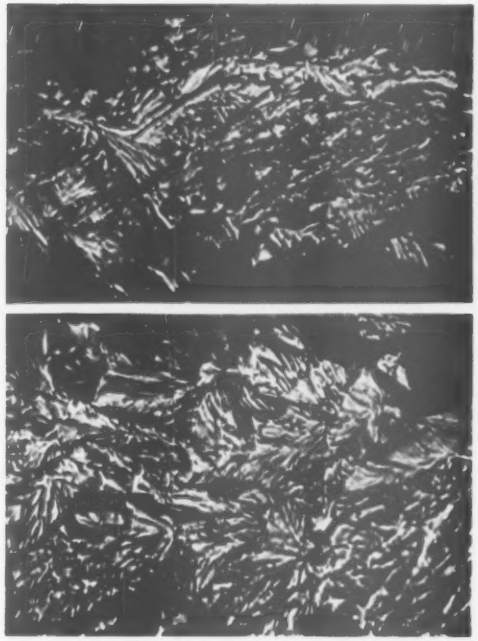


Fig. 11 Unusual facets found in Specimen 3

These patterns are unlike any of the preceding in showing multiple-lineage growths within the single grain, in contrast, for example, to the pattern of Fig. 9. 800 ×. (Reduced ½ in reproduction)

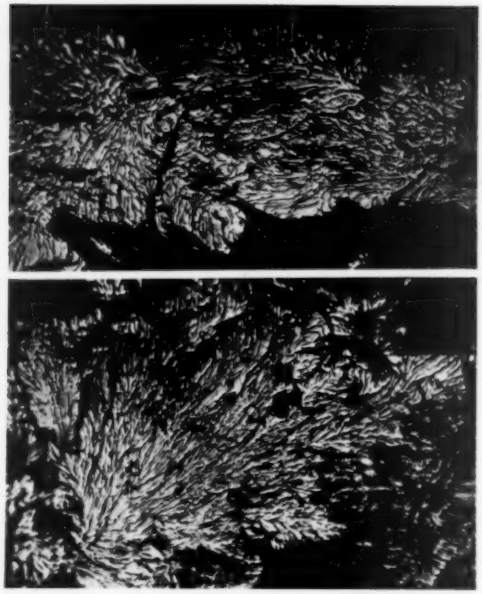


Fig. 12 Cleavage facets in 6012 weld metal

These facets are relatively flat and have some fivefold greater area than most of the preceding, necessitating a lower magnification to contain a single facet on the plate. The patterns therefore indicate a metal of inferior mechanical properties, which is in agreement with general experience. Specimen 8. 350 ×. (Reduced 1/3 in reproduction)

enclose one facet on the plate; and the pattern is one of inferior toughness.

Type E6020 Electrodes

Using an E6020 mineral-coated electrode, one generally obtains a weld deposit having good ductility and toughness. This is corroborated by the fractographs in Fig. 13 which show a rugged traverse and compare closely with the patterns for 6015 in the previous Fig. 9.

High-Phosphorus Electrodes

Using an E6015-type coating with phosphorus added, one obtains an extremely brittle bead. Once again a reduced magnification is required to get even the major portion of a single facet on the plate, as shown in Fig. 14. Note the extreme flatness of the field and the expansiveness of the facet, indicating ready cleavage traverse through this metal.

Particularly in the lower fractograph of Fig. 14, one observes a wavy pattern which seems to be peculiar to this metal and to indicate a rather elaborate dendritic expression of the individual lineage or subgrain units. This is much more pronounced in Fig. 15, where a fracture pattern of elaborate design is produced. Only in the previous Fig. 5 has such a visibly dendritic pattern been observed, and there it was an exception.

Here it is the rule. The high-phosphorus metal is

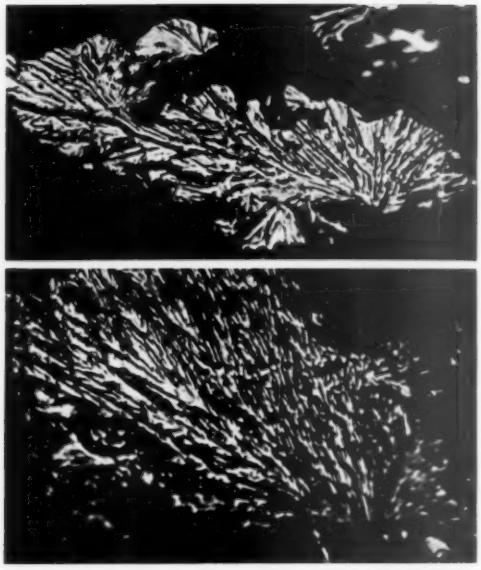


Fig. 13 Cleavage facets in 6020 weld metal

The facets express toughness, comparing well with 6015 metal in Fig. 9. Specimen 5. Fractured at room temperature. 800 ×. (Reduced 1/3 in reproduction)

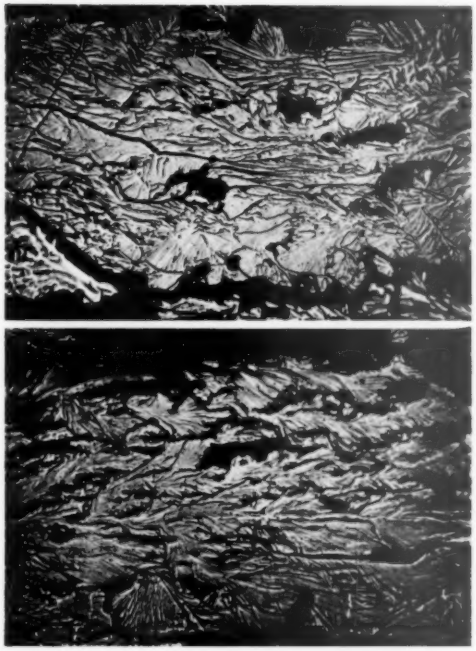


Fig. 14 Cleavage facets in high-phosphorus weld metal

The facets in this metal are typically large and flat with a pronounced tendency toward the elaborate pattern indicated in the lower fractograph and developed to high degree in the following figure. Specimen 4. Fractured at −196° C. 450 ×. (Reduced 1/3 in reproduction)

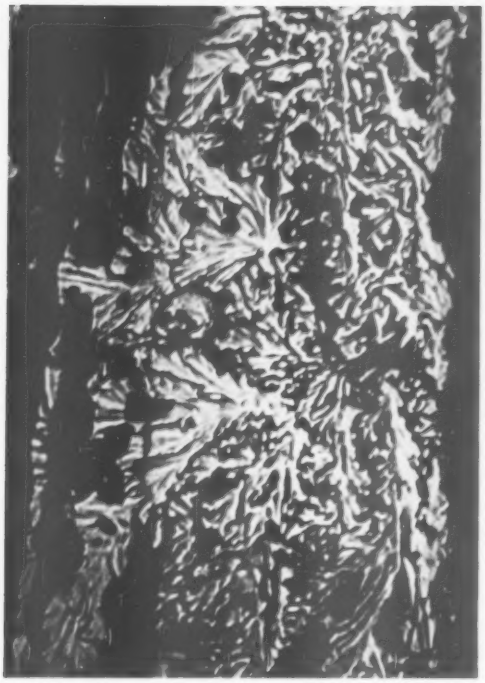


Fig. 15 Fractograph of high-phosphorus weld metal showing typical elaborate dendrite pattern

Apparently the metal can be identified by this frequent floral design on its cleavage pattern. Specimen 5. Fractured at 196° C. 975 ×. (Reduced 1/3 in reproduction)

readily identified by the pattern type shown in Figs. 14 and 15.

CONCLUSIONS

From this preliminary survey of weld fractures in beads from common electrode types, the following conclusions can tentatively be drawn:

1. Fractography is applicable to weld fractures.

2. The toughness of weld metal can be given useful qualitative rating on the basis of the fractographic pattern.

3. Type E6010 electrode deposits are visually inferior to E6015 and E6020 deposits on the basis of toughness pattern.

4. Improperly dried Type E6015 electrode produces weld metal having as poor a toughness rating as E6010 metal.

5. Normally dried Type E6015 indicates the best toughness properties in its weld deposit for all types tested, though there is ample evidence that "hydrogen-free" is a relative term still leaving room for improvement.

6. Further drying a baked E6015 electrode by short circuiting just previous to welding may afford some further improvement.

7. Burning away of the electrode during welding serves to dehydrate remaining portions, such that an improperly dried E6015 electrode delivers improved metal from front-to-rear of the bead.

8. Type E6020 electrode produces metal of quality similar to E6015, though possibly slightly inferior.

9. Type E6012 produces large and flat facets indicating markedly inferior toughness.

10. Type E6015 with phosphorus added to yield 0.39% P in the bead produces a highly inferior deposit on the basis of toughness pattern, the facets being expansive, relatively flat and containing a peculiar branching or floral pattern by which such metal can be identified.

11. A novel observation of "intragranular gassiness" is made for E6010 deposit, consistent with the known hydrogenizing propensity of this electrode and introducing the fisheye phenomenon on a subgranular scale.

ACKNOWLEDGMENT

Acknowledgment is made to the Office of Naval Research under whose sponsorship this research was conducted; and to Dr. G. E. Claussen and the Reid-Avery Co., for cooperation in conducting the welding experiments.

Bibliography

1. Zapffe, C. A., and Clogg, M., Jr., "Fractography—A New Tool for Metallurgical Research," *Trans. Am. Soc. Metals*, **34**, 71–97; disc., 98–107 (1945).
2. Zapffe, C. A., "Étude Fractographique Des Alliages Fer-Chrome," *Rev. Metallurgie*, **44**, (3–4), 91–96 (1947).
3. Zapffe, C. A., Worden, C. O., and Landgraf, F. K., "Fractographic Examination of Ship Plate" THE WELDING JOURNAL, **28**, (3) Research Suppl., 126-s to 135-s (1949)
4. Zapffe, C. A., Worden, C. O., and Landgraf, F. K., "Cleavage Patterns Disclose 'Toughness' of Metals," *Science*, **108**, No. 2808, 440–441 (1948).
5. Zapffe, C. A., and Moore, G. A., "A Micrographic Study of the Cleavage of Hydrogenized Ferrite," *Trans. Am. Inst. Mining Met. Engrs.*, **154**, 335–352; disc., 352–359 (1943).
6. Zapffe, C. A., and Sims, C. E., "Defects in Weld Metal and Hydrogen in Steel," THE WELDING JOURNAL, **19** (10), Research Suppl., 377-s to 395-s (1940).
7. Herres, S. A., "Practical Importance of Hydrogen in Metal-Arc Welding of Steel," *Trans. Am. Soc. Metals*, **39**, 162–189; disc., 189–192 (1947).
8. Hoyt, S. L., Sims, C. E., and Banta, H. M., "Metallurgical Factors of Underbead Cracking," *Metals Tech.*, **12**, T. P. 1847, 24 pp. (1945).
9. Daniels, F. W., Gardner, F. S., and Rood, R. M., "The Comparative Behavior of Mild-Steel Welds Made with E6010 and E6016 Electrodes," THE WELDING JOURNAL, **27** (9), Research Suppl. 436-s to 440-s (1948).
10. Bunn, W. B., "Low-Temperature Charpy Tests of Various Ferritic Weld Deposits." Presented at A.W.S. Annual Meeting, Oct. 21, 1947.

Development of Specimen Simulating Weld Heat-Affected Zones

The design and construction of a time-temperature control device for the exact duplication of weld heat-affected structures for testing purposes

by Ernest F. Nippes and Warren F. Savage

SUMMARY

A TIME-temperature control device was designed and constructed which permitted exact duplication of the heating and cooling cycles experienced by regions adjacent to an arc weld. The mathematical relationships described in a previous report[1] provided the foundation for this work. In a later report the results of the initial application of this device will be discussed in detail. Included in the present report is a discussion of the metallography of an arc weld and the historical background which led to the development of this control device.

INTRODUCTION

Any study of the joining of steels by the electric arc-welding process necessitates treatment of the welded member as an agglomeration of metallurgical phenomena. The welded joint may be considered as comprised of two major portions:

1. The region where temperatures in excess of the melting temperature of the material involved are realized, commonly referred to as the fusion zone.

2. A complex portion, extending outward from the boundary of the fusion zone, in which the original microstructure has been altered by the welding process; known as the heat-affected zone.

The production of a satisfactory arc weld demands that the mechanical properties of both portions shall be adequate to satisfy the service requirements for the member. Much has been written regarding the virtues of welding as a means of fabrication, and articles extolling the strength and other desirable properties are very numerous. The welding engineer, however, recognizes that the production of a satisfactory weld often necessitates a knowledge of the metallurgical phenomena influencing the production of the fusion zone and the heat-affected zone.

A DISCUSSION OF THE METALLOGRAPHY OF AN ARC WELD

Arc welding may be considered as a casting operation in which the metallic electrode is the source of filter material; the arc, the source of heat for melting; and the space between the members to be joined is both the mixing crucible and the mold in which the metal is cast. In order to secure a satisfactory bond, the arc and the heat from the deposited molten metal must melt the boundary surfaces of the members, and some mixing of the molten weld metal and molten plate metal must occur. This having been accomplished, the molten metal in the fusion zone cools by radiation to the atmosphere, but primarily by conduction of heat away from the fusion zone by the members being welded. It is this conduction of heat away from the fusion zone that produces the complex heat-affected zone. Figure 1* shows the temperature distribution at various times after the deposition of the molten metal in the groove, referred to temperatures on an iron-carbon diagram. The curve marked *2* shows this temperature distribution 2 sec. after the arc passed the cross section shown at top in Fig. 1, and the steep temperature gradient from the zone outward into the plate material should be noted. During the period following deposition of the weld metal, a region of the

* The temperature distributions shown are those associated with an electric arc weld made in ½-in. mild steel plate using an energy input of 70,000 joules per inch. Data for these curves are included in Appendix I.

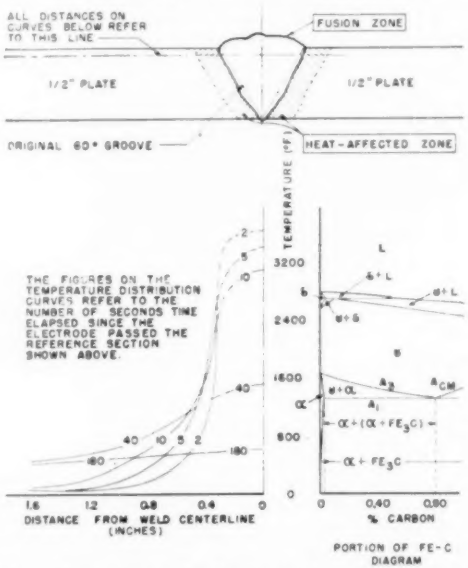


Fig. 1 Temperature distribution in the neighborhood of an electric arc weld

Ernest F. Nippes and **Warren F. Savage** are associated with the Welding Laboratory of the Department of Metallurgy at Rensselaer Polytechnic Institute, Troy, N. Y.

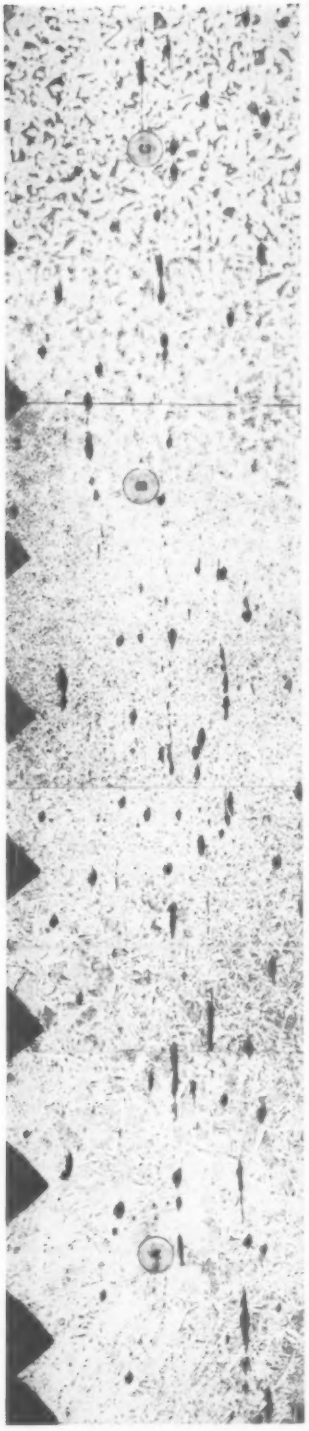


Fig. 2 Panorama showing microstructures associated with an arc weld made in 1/2-in. plate using an energy input of 70,000 joules per inch. 50 ×

welded member adjoining the fusion zone is heated to temperatures above the lower critical temperature, and this region comprises the so-called heat-affected zone.

Figure 1 also expresses the temperature distribution during this period following deposition of the weld metal, diagrammatically. The curves labeled $t = 2$, $t = 10$, $t = 180$ indicate the temperature distribution found in the neighborhood of an arc weld at 2, 10, and 180 sec. after the arc passes the cross section shown. It should be noted that both the maximum temperature and the rate of cooling obtained in the heat-affected zone vary inversely with the distance from the weld center line.

The changes in microstructure produced by a weld in 1/2-in. ship steel using an energy input of 70,000 joules per inch are shown in Fig. 2. The production of these changes may be summarized as follows. In withdrawing heat from the fusion zone the material at *A*, immediately adjacent to the fusion zone is heated far into the austenitic range, and therefore grain growth causes large austenitic grains. The maximum temperature attained and therefore the size of the austenitic grains diminishes with increasing distance from the fusion zone, until *B*, Fig. 2, is reached where the transformation to austenite is just complete. Beyond this point the extent of austenitization decreases, until at a point *C* the maximum temperature is so low that presumably no austenite is formed. It must, however, be borne in mind that the time for these reactions to occur is rather short, being of the order of magnitude of seconds, and therefore temperatures required to produce the observed metallographic changes are always considerably higher than the temperatures which govern equilibrium reactions. As time passes, the temperature distribution changes, as indicated by Fig. 1, until the whole member returns eventually to ambient temperature. The cooling rates also vary from point-to-point in the heat-affected zone, the rate of cooling varying in the same order as the maximum temperature attained at any point, and thus further influencing the resultant microstructure.

Since general metallographic structural variations found in an arc-welded member reflect the thermal history of the point in question, these variations in the microstructure may now be discussed. For reference purposes, each region will be identified in Fig. 2.

1. The Fusion Zone. The high temperature gradient, and resultant high cooling rate, associated with the edge of the fusion zone promote nucleation at the edge of the fusion zone; and, because of the relatively rapid cooling rate, growth tends to dominate the solidification from this stage on, resulting in a columnar dendritic grain structure. The axis of these columnar grains being approximately perpendicular to the edge of the fusion zone indicates this rapid growth from many closely spaced nuclei.

2. Region of Grain Coarsening. The region experiencing maximum temperatures well in the austenitic region exhibits large grain sizes, and the relatively rapid cooling rates are evidenced by the typical Widmanstätten structure found in the neighborhood of the fusion zone. The grain size resulting is a maximum at the edge of the heat-affected zone near the fusion zone, and diminishes rapidly with increasing distance from the fusion zone. In hypoeutectoid steels the fast cooling rate also results in some suppression of the amount of free ferrite found in this region of the heat-affected zone.

3. The Region of Grain Refinement. The region heated just above the temperature required for complete austenitization exhibits a totally refined equiaxed grain structure. The grain size presumably is a minimum where a maximum temperature in the neighborhood of the effective upper critical temperature (Ac_3) is realized.

4. The Region of Partial Refinement. Bordering the region of refinement and extending outward is a region of partial refinement produced by the partial austenitization experienced. In hypoeutectoid steels those portions richest in carbon exhibit extremely fine grain structure, while the ferritic regions become less affected as the maximum temperature attained diminishes, and tend to approach the original grain size.

5. The Region of Spheroidization. Over a narrow region heated in the neighborhood of the effective lower critical temperature, the lamellar carbides tend to dissolve on heating and reform as spheroidal particles upon cooling. This region of spheroidization in hypoeutectoid steels is characterized by colonies of spheroidal carbide particles within the areas originally pearlitic. The matrix of ferrite remains unaffected by the relatively low maximum temperature reached in this region. Beyond this region of spheroidization, structural changes are not observed by any of the usual microscopic methods, although precipitation phenomena may possibly be present.

From this discussion it becomes evident that the heat-affected zone as originally

defined is in reality a conglomeration of metallurgical changes wrought by the thermal history of the particular region. Since it is a known metallurgical fact that the properties of a material depend upon the microstructure, the answers to the problems of weldability may well be sought in the heat-affected zone.

HISTORICAL BACKGROUND

Previous work by Hess, Merrill, Nippes, *et al.*,[1] at the Rensselaer Polytechnic Institute Welding Laboratory, involving the measurement of cooling rates associated with arc welding, led to the development of a system of quantitative prediction of cooling rates as a function of welding variables. Measurements obtained by embedding thermocouples in the plate material near an arc weld confirmed that the following welding variables influence the cooling rate at a point in the vicinity of an arc weld:

1. Weld energy input
2. Joint geometry
3. Plate thickness
4. Initial plate temperature

The weld energy input is a combined variable including the arc current, arc voltage and arc travel speed.* It may be represented as follows:

$$\text{Weld energy input} = \frac{\text{Arc voltage} \times \text{arc current}}{\text{Electrode travel speed}} \times 60 \quad (1)$$

The quantities are expressed in the following units:

Arc voltage, volts
Arc current, amperes
Arc travel speed, inches per minute

The energy input will then be expressed in watt-seconds per linear inch of weld, or more conveniently, joules per inch. Since the arc is the sole source of heat, the energy input is significant as determining the rate of application of heat to the fusion zone.

The joint geometry affects the rate of heat dissipation from the fusion zone, and exerts a complex influence on the cooling rates associated with arc welding. For the purpose of the present investigation the joint geometry assumed is that of a butt weld with a 60° included angle between the prepared faces of the plates.

The study of cooling rates has ascertained that the plate thickness influences the mechanism of heat transfer from the fusion zone only if the plates are below a certain critical thickness. This critical thickness is influenced by the diameter of the electrode employed, and the energy input. However, for most normal welding conditions up to energy inputs of 100,000 joules per inch, used with $^5/_{16}$-in. electrode, thicknesses of over 1.0 in. act as plates of infinite thickness, and thus simplify the mathematical analysis somewhat.

The final factor, namely, the initial plate temperature, determines the thermal gradient and thus influences the cooling rates. High initial plate temperatures tend to reduce the temperature difference between the fusion zone and the plate, or low temperature heat reservoir, and therefore reduce the cooling rates experienced by the heat-affected zone.

A systematic investigation of the effects of these variables was employed to evaluate the necessary constants in a mathematical expression relating the cooling rates experienced by any point in the heat-affected zone to these welding variables. Tables of these cooling rate values for a tremendous variety of welding conditions are available in the literature;[1] and by application of these tabulated values of cooling rates, together with information obtained from a standard Jominy hardenability test, a more intelligent selection of the welding variables for welding hardenable steels is possible.

The above investigation, in turn, led to the development of a series of differential equations[2] expressing the temperature distribution in the neighborhood of an electric arc weld as a function of time, distance from weld center line and welding variables. These equations have the general form:

$$T - T_0 = \frac{F(s, d)}{1000} \times \text{Energy input} \times \text{input factor}$$

where

T_0 = initial plate temperature in ° F.

$F(s, d)$ = function of the distance, d, from the weld center line, and the time, s, after the electrode passes the point.

Energy input = weld energy input expressed in joules per inch.

Input factor = a multiplying factor which accounts for the effect of preheat temperatures and is discussed in detail in references 1 and 3. The value of this factor is 1.0 for initial plate temperature of 72° F., and other values are employed for other initial plate temperatures.

T = the temperature in ° F. of a point, d, of distance, d, from the weld center line at the end of time, s, after the arc passes the point.

By means of these equations the temperature at a point, d, of distance, d, from the weld center line, at the end of s sec. after the arc passes the point may be readily obtained. By calculation of the temperature at such a point, d, as a function of time over the range 2 to 180 sec. after the arc passes, the complete heating and cooling cycle for the point may be obtained. If this heating and cooling rate were then to be exactly duplicated in a specimen of the same steel, the microstructure found at the point, d, near an arc weld would be exactly reproduced in the specimen.

The use of this method for the reproduction of the microstructures associated with the heat-affected zone of an arc weld, in specimens of suitable form for convenient testing, was the object of a research program sponsored by the Weldability Committee of the Welding Research Council. The original method of attack was as follows:

1. Specimens of suitable size for impact testing were clamped in the jaws of a flash welder.

2. The specimen was heated by its own resistance to the passage of an electric current of controlled magnitude.

3. Heating rates were adjusted to match the heating rate associated with the desired point in the heat-affected zone of an arc weld by electronically adjusting, as a function of time, the magnitude of the current passing through the specimen.

4. Cooling of the specimen occurred by conduction of heat in a longitudinal direction to the water-cooled jaws of the flash welder.

5. The rate of cooling was adjusted by passing small pulses of current through the specimen in order to reduce the cooling rate.

6. By electronic control of the magnitude of this current as a function of time the cooling rate in the specimen was at all times adjusted to match the cooling cycle experienced by the desired point in the heat-affected zone of an arc weld.

This method, though it did confirm the possibility of reproducing some of the metallographic structures found in the heat-affected zone of an arc weld, proved to present overwhelming difficulties in reproducing the desired structure consistently. Apparent minor discrepancies in the dimensions of the specimen made adjustment of the many required current magnitudes, and the respective time intervals for each magnitude of current a practical impossibility. It was therefore proposed that the control system be redesigned to insure positive reproduction of any desired microstructure by consistent, exact duplication of the related heating and cooling cycle. The purpose of this report is, therefore, to present the solution to this problem of design. In a subsequent report the nature of the test results on specimens produced by application of the foregoing information and the newly designed apparatus will be presented.

* It was found that in the range normally associated with manual arc welding, 5 to 12 in. per minute, the arc travel speed has no effect on the cooling rate, thus justifying the choice of this combined variable. However, it should be pointed out that according to Jackson[2] the high travel speeds associated with the submerged arc-welding processes, 20 in. per minute and up, necessitate consideration of the arc travel speed as an independent variable.

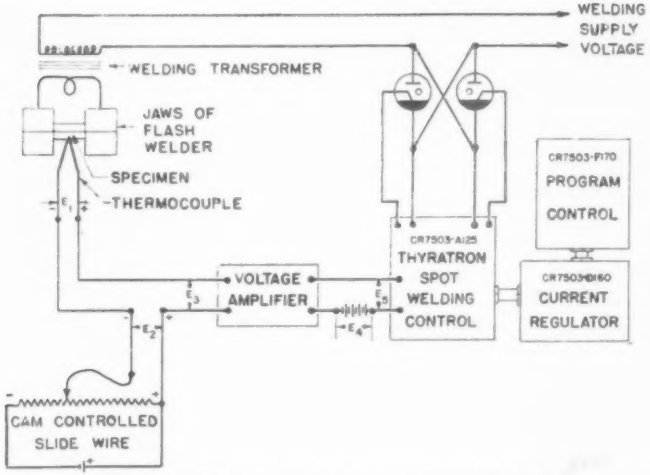


Fig. 3 Simplified schematic of automatic control device

OBJECT

The object of this investigation was the design and construction of a device to permit reproduction of the microstructures found at any point in the heat-affected-zone of an arc weld. The following conditions were to be satisfied:

1. The desired microstructure was to be reproduced in a specimen of suitable form and dimension for impact testing, by duplicating in the specimen the exact heating and cooling cycles experienced by a point, having the same microstructure, in the heat-affected zone of an arc weld.

2. The desired microstructure was to be reproduced over a sufficient volume of the specimen to insure a significant test of the impact properties of that structure.

3. The device, as designed, was to insure consistency in the reproduction of the microstructure.

4. The necessary control mechanism was to be automatic in its function in so far as possible.

SCOPE

The following limitations were imposed upon the design of the device:

1. A specimen approximately 0.4 in. square and 3-in. long was to be clamped in the jaws of a flash-welding machine at a convenient operating position.

2. The specimen was to be heated by its own resistance to the passage of an electric current.

3. The cooling of the specimen was to occur by the transfer of heat in a longitudinal direction to the water-cooled jaws of the flash welder.

4. An electronic device was to be perfected which would turn the current on or off in such a way as to heat the specimen or allow it to cool as required.

5. The electronic device was required to maintain this on-off control in such a way as to insure the exact duplication of the desired heating and cooling cycle.

6. A cam-operated mechanism was to establish and assist in maintaining the desired heating and cooling cycle.

7. The cams for establishing the heating and cooling cycle were to be simple to construct and readily interchangeable.

8. A fine wire thermocouple securely welded to the sample was to provide a continuous control of the heating and cooling cycle based on the actual instantaneous temperature of the specimen and the heating and cooling cycle established by the cam.

9. Wherever possible, existing apparatus for the control of resistance welding operations was to be employed in order to simplify design.

DELIMITATIONS

This device was specifically designed to permit reproduction of the heating and cooling cycles found in the heat-affected zone of arc welds made under the normal operating conditions associated with manual arc welding. The device was not intended for duplication of cooling cycles in excess of 200° F. per second at 1300° F., although the maximum cooling rate which has yet been obtained using this device was 330° F. per second at 1300° F. The upper limit of the heating rate was to be sufficiently high to permit heating of a specimen from 72 to 2500° F. in less than 2 sec. It should be mentioned that these maximum heating and cooling rates were to be obtained with a relatively small jaw separation, i.e., free length of specimen, and the region of metallographic uniformity was thereby to be reduced somewhat in length.

GENERAL DISCUSSION OF THE DESIGN PROBLEM

The fundamental principles employed in this control device are not, by themselves, original. Several manufacturers of control devices have marketed program controllers designed to regulate time-temperature cycles for industrial heat-treatment work. Such control devices are commercially available, employing the same basic principles of control described in this report, but the over-all speed of response is too slow to be useful for the problem at hand. The control device here described must function satisfactorily over the same temperature range, but the speed of response must be of the order of milliseconds, rather than minutes or hours. The ordinary program control device has an over-all speed of response which is limited by the rate of heat transfer from the heat source, i.e., gas flame, furnace element, etc., to the workpiece. Therefore, in order to obtain the necessary speed of response for the reproduction of the rapid heating and cooling cycles associated with arc welding, it was decided to heat the specimen directly by its own resistance to the passage of an electric current.

Mercury relay contactors are entirely satisfactory for regulation purposes in industrial heat-treatment service, but the extremely rapid speed of response required, necessitated employing electronic tubes as contactors in this design. In that the electronic tubes have no moving parts, there are no contacts to wear or pit in service, and operation is noiseless and free of inertia difficulties.

Figure 3 shows a simplified schematic diagram of the device for duplicating the desired time-temperature cycles. The specimen, clamped in the jaws of a flash welder,* is indicated in the upper left-hand corner of the diagram. The thermocouple attached to the specimen produces a small voltage, E_1, which is proportional to the specimen temperature. The cam-controlled potentiometer slide wire is connected in series with the thermocouple so that the small reference voltage, E_2, obtained from the slide wire is of opposite polarity to the output voltage of the thermocouple. The voltage, E_3, appearing at the input to the voltage amplifier is, therefore, the algebraic sum, $E_1 + E_2$, and will hereafter be referred to as the unbalance voltage. The magnitude and polarity of this voltage, E_3, depends on the instantaneous values of E_1, which is proportional to the specimen temperature, and E_2, which is pro-

* It should be emphasized that the flash welder was chosen only as it presented a convenient means of holding the specimen while subjecting it to the desired time-temperature cycle by means of the control device.

portional to the temperature desired at that instant.

The function of the control is to adjust the temperature of the specimen automatically, so that the output voltage of the thermocouple will balance the output voltage of the cam-controlled potentiometer slide wire. This condition of balance provides an unbalance voltage, E_2, of zero at the input of the amplifier, and is therefore called a condition of correspondence. Should a departure from correspondence occur, the magnitude and polarity of the unbalance voltage at the input to the amplifier determines the nature of the amplified control signal appearing at the amplifier output. This amplified signal, together with a suitable bias signal, is then applied to the grid of the leading tube of a modified General Electric CR7503-A125 Spot Welding Control. The application of this grid signal causes the control to regulate the operation of an ignitron contactor in series with the primary of the flash-welder transformer. This in turn controls the flow of current through the specimen in such a way as to almost instantaneously re-establish a condition of correspondence. It is, therefore, apparent that the entire control device forms a closed loop characteristic of a servo-mechanism, whereby a small error signal is employed to control and modify external conditions which produce the error signal.

The heating portion of the desired time-temperature cycle determines the maximum power input demand. During the cooling portion of the time-temperature cycle the maximum cooling rate obtainable must always exceed the cooling rate desired. In order to adjust the cooling to the desired rates, current must then flow intermittently, and the power input during cooling is therefore low. In order to make possible adjustment of the power level to more closely match the demands of a particular period of the time-temperature cycle, further refinements were therefore made on the control system. The current magnitude available at any particular time is determined by the settings of a General Electric CR-7503-F170 Program Control, used in conjunction with a General Electric CR7503-D160 Current Regulator Control. These controls permit establishing ten consecutive, independently adjustable time intervals, during each of which the current magnitude is determined by a dial setting. The current magnitude during each interval is expressed as per cent heat, and is adjusted at the outset of the process to provide the desired power levels at various periods of the time-temperature cycle.

The over-all device is of necessity somewhat complicated and it is therefore proposed to consider the problem as comprised of four main divisions as follows:

1. The design and construction of the cam-controlled potentiometer.
2. The design and construction of the voltage amplifier.
3. The design and construction of suitable biasing arrangements.
4. Interconnection with existing equipment.

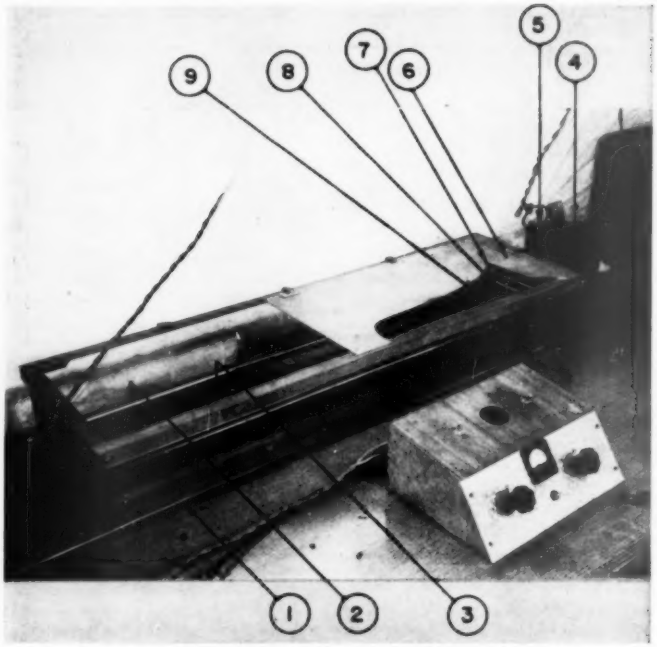


Fig. 4 Close-up of cam-controlled potentiometer

THE CAM-CONTROLLED POTENTIOMETER

The function of the cam-controlled potentiometer is to create the necessary reference voltage, which when balanced against the thermocouple output establishes the point of temperature correspondence previously discussed. Figure 4 is a photograph of the present cam-driven potentiometer design, and Fig. 5 constitutes a working drawing of the same potentiometer. The salient features of the design are indicated by means of numbered arrows, which will be referred to in the following description of Fig. 4.

The base, *1*, of the cam-operated potentiometer is made from a piece of $^1/_2$- x 12- x 48-in. cold-rolled steel plate in order to insure rigidity and unchanging relative positions of the other components. Two main ways, *2*, of 1-in. surface ground drill rod, are supported in a parallel position by means of two pieces of machined $^3/_4$- x 8-in. angle, as shown in Fig. 5. The drive motor, *4*, is an Esterline Angus 600-rpm., 110-v. a.-c., synchronous, single-phase motor equipped with a solenoid-actuated, *5*, clutch engaging a worm gear drive, having a 10:1 reduction. It is mounted on a bracket at one end of the base plate and connected to the drive screw, *3*, by means of a flexible coupling. The drive screw is a $1^1/_4$-in. diameter screw, having 12 threads per inch, and is mounted in self-aligning ball bearings. The drive screw rotates at 60 rpm. and thus establishes the time scale for the cam of 5-in. travel per minute, in a direction parallel to the main ways, *2*.

The cam, *6* is secured to a rigid mount made of 1-in. brass angle, attached to the main supporting angles. The design of cams for reproduction of time-temperature cycles will be discussed later in this report.

The cam follower, *7*, is mounted on two transverse ways, each made of $^1/_4$-in. diameter drill rod, and is held in intimate contact with the cam by means of a counterweighted cord. Beneath the two transverse ways is fixed the slide wire, *8*, which runs parallel to the ways, in the transverse direction. The sliding contact is fixed on the undersurface of the cam follower, and its relative position on the slide wire is therefore determined by the cam, at any given instant. The entire transverse assembly, including ways and cam follower, is mounted on a travel carriage, *9*, made of $^1/_2$- x 5- x 9-in. steel plate. The slide wire and all associated electrical connections are insulated from the cam mechanism by $^1/_4$-in. Micarta board.

In order to minimize friction losses,

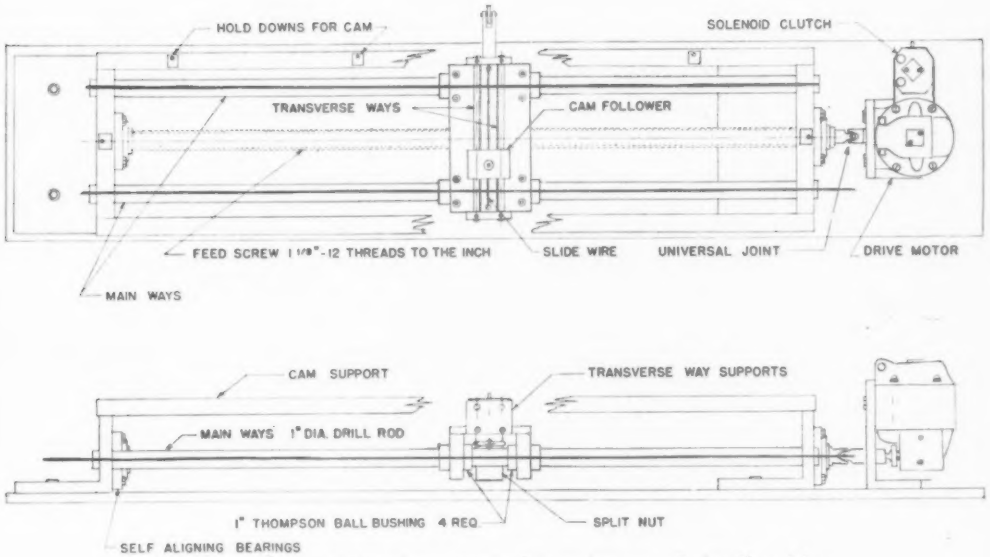


Fig. 5 Assembly drawing of cam-operated potentiometer. Scale: 1/4 = 1 in.

and insure smooth operation, Thompson ball bushings are employed on both the travel carriage, *9*, and the cam follower, *7*. These ball bushings are unique in that they employ balls, mounted in oval races, to provide rolling contact at all times. A further advantage is gained, in that the close dimensional tolerances obtained prevent sideplay in the sliding mechanisms.

The travel carriage, *9*, is driven along the main ways by a split nut attached to the under side of the travel carriage, and engaged with the drive screw. A lever is provided to disengage the split nut from the main drive screw during changing of cams and calibration.

Figure 6 shows the wiring diagram of the potentiometer slide wire circuit. Current in the slide wire is obtained from three No. 6 dry cells connected in parallel to furnish a potential of 1.5 v. The variable resistance, R_A (1000 ohm) is employed to limit the current in the slide wire, and thus establish the millivolt (temperature) scale of the cam. The slide wire was made in the form of a 0.012-in. diameter Manganin wire, spiral wound on a 0.032-in. diameter form. The over-all free length of the slide wire is 8 1/2 in., with a resistance of 1.38 ohms per linear inch.

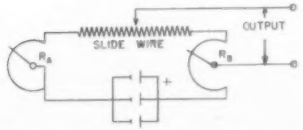


Fig. 6 Wiring diagram of the potentiometer slide wire circuit

The potentiometer R_B is employed to increase the output of the potentiometer by as much as 20 mv. without changing the calibration. It will be noticed in Fig. 6 that one of the output leads is attached at the movable contact point on R_B (a 20-ohm potentiometer) in order to accomplish this without changing the ohmic resistance of the supply current path. Switch S_1 is a double-pole single throw switch and serves to turn the potentiometer current off, and also to disconnect one lead from the external circuit. The current supply to the slide wire and all controls are conveniently mounted on the enclosed panel shown at front of Fig. 4.

CALIBRATION OF THE CAM-OPERATED POTENTIOMETER

The cam-operated potentiometer is readily calibrated by connecting a portable potentiometer across the output leads, and adjusting the current through the slide wire, by means of the variable resistor R_A (Fig. 6). The current through the slide wire is adjusted to obtain the desired voltage drop in the slide wire, usually stated in millivolts per inch. (The slide wire calibration is usually made 4.0, 5.0 or 8.0 mv. per inch and the cams are cut to give the desired outputs on the basis of the calibration used.)

CONSTRUCTION OF CAMS

Cams are made out of 0.064-in. magnesium sheet, since this material is readily machined to the desired dimensions. A linear time scale of 5 in. per minute is scribed on the sheet, extending from right to left longitudinally (see cam, *6*, in Fig. 4). The temperatures as a function of time are converted to the proper values of millivolts as a function of time, by means of the appropriate temperature-millivolt conversion table for the thermocouple alloys used. These values are then converted into transverse displacement values by dividing the values, in millivolts, by the appropriate calibration of the slide wire, in millivolts per inch. These transverse displacement values are then laid out on the corresponding time line, previously scribed, starting from some convenient base line. The points resulting are then connected by a smooth curve, and a correction applied to account for the diameter of the cam follower. The resulting curve is then carefully machined from the sheet, forming a cam such as is illustrated, *6*, in Fig. 4.

The cam is then placed on the rigid support above the cam follower mechanism, properly positioned, and rigidly fastened by means of lugs attached to the cam support. In order to insure proper positioning of the cam, the output of the cam-operated potentiometer is checked against a portable potentiometer at several points, corresponding to times where the exact values of the desired output voltage are known.

DESIGN OF THE VOLTAGE AMPLIFIER

Since high gain d.-c. amplifiers are inclined to be inherently unstable, it was decided to convert the small d.-c. unbalance signal into a small a.-c. unbalance signal by means of a Brown Synchronous

vibrator. No detailed information is available about the structural details of this mechanism, but Fig. 7 includes a schematic of the synchronous vibrator. Essentially, it consists of a pair of contacts mounted on a reed, which is vibrated in phase with an a.-c. supply voltage by a current through a magnetizing coil near the reed. The opposite end of the reed is between the pole pieces of a small permanent magnet, and is alternately attracted and repelled by these poles, according to the direction of the current in the magnetizing coil.

The small d.-c. voltage, E_3, tends to force a current through the reed to one of the contacts, through one-half of the input transformer secondary, out the center top and back to source, E_3, again. Since the reed vibrates in synchronism with the a.-c. supply to the magnetizing coil, the current flow through the reed is transferred from one end of the input transformer to the other in synchronism with the a.-c. supply voltage. The result is the production of a voltage, E_3', at the secondary of the input transformer, having a modified square wave shape, as shown in Fig. 7. This voltage wave has a fundamental frequency equal to the a.-c. supply frequency at the magnetizing coil, and bears a definite phase relationship to this a.-c. supply. Depending upon the polarity of the small d.-c. supply voltage, E_3, the voltage, E_3', will either be exactly in phase with (as in Fig. 7) or 180° out of phase with the a.-c. supply voltage (as in Fig. 8).

E_3', then, is the actual input to the amplifier. It is an alternating voltage of the form of a modified square wave, having a fundamental frequency fixed by the a.-c. supply voltage, a magnitude which is proportional to the d.-c. unbalance voltage, E_3, and is either in phase with, or 180 electrical degrees out of phase with the a.-c. supply voltage to the magnetizing coil. By the transformation of the d.-c. unbalance voltage, E_3, to an a.-c. unbalance signal E_3' the use of an a.-c. voltage amplifier was made possible.

The requirements of the voltage amplifier were rather stringent, even with the above modification. The phase relationship of the a.-c. unbalance signal must be retained with the least possible amount of phase distortion in order to secure proper over-all operation of the control device. Furthermore, since the undistorted amplification of a square wave requires that the gain of the amplifier be essentially flat from the fundamental frequency of the square wave up to a frequency equivalent to the seventh or eighth harmonic, the frequency response characteristics must be carefully considered in the design of the amplifier. Finally, it was found that the gain of the amplifier must vary inversely with the magnitude of the unbalance signal, E_3', appearing at the input to the amplifier. Figure 9 shows a schematic wiring diagram

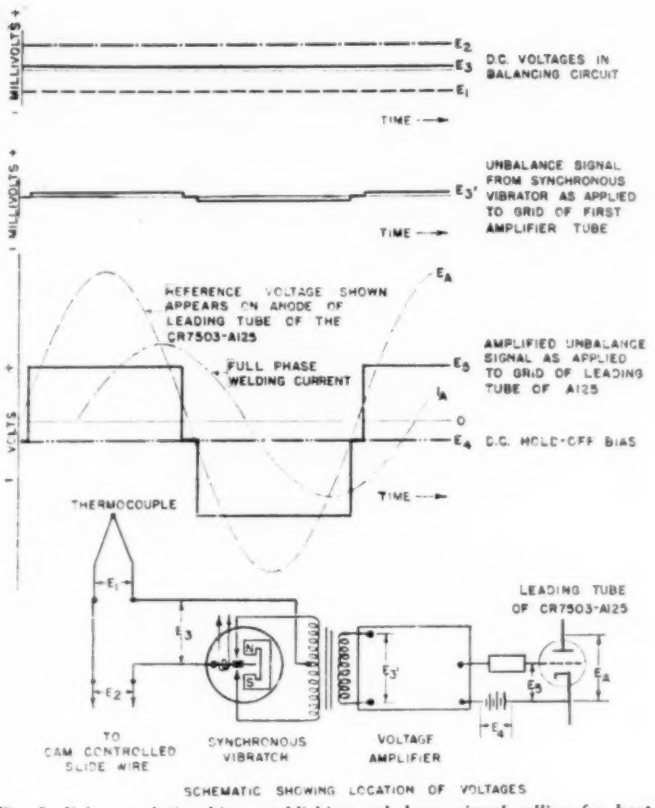


Fig. 7 Voltage relationships establishing unbalance signal calling for heat

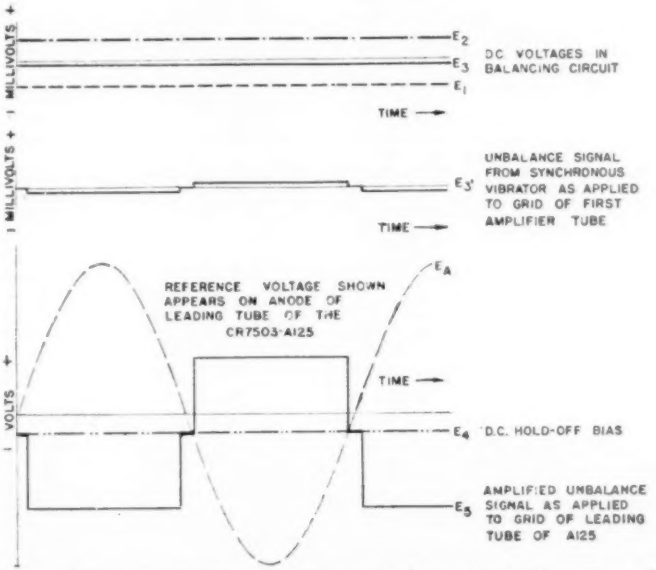


Fig. 8 Voltage relationships establishing unbalance signal calling for cool

of the resulting amplifier. Table 1 includes the circuit constants and parts list for this amplifier design.

The over-all gain characteristics of the present amplifier are indicated in Fig. 10. All measurements refer to peak values of input and output voltages and represent

Table 1—Circuit Constants for Amplifier Shown in Fig. 9

Transformers:
- T_1—Power transformer
- T_2—Thordarson input transformer, T43G06A 75981
- T_3—Thordarson interstage transformer, T19D03

Resistors:
- R_1, R_2, R_3, R_4, R_5—100,000 ohms, 1 w.
- R_6—1200 ohms, 1 w.
- R_6, R_7, R_{14}, R_{16}—51,000 ohms, 1 w.
- R_7—2000 ohms, 1 w.
- R_9—10,000 ohms, 1 w.
- R_{10}—500,000 ohms, potentiometer
- R_{11}—3600 ohms
- R_{13}—500,000 ohms, 1 w.
- R_{15}—5000 ohms, 1 w.
- R_{17}, R_{18}—520,000 ohms, 1 w.
- R_{18}—390 ohms, 1 w.

Condensers:
- C_1—10/10/10 mf., 600 v., electrolytic
- C_2—0.015 mf., 600 v., paper
- C_3, C_4, C_5, C_6, C_7—0.05 mf., 600 v., paper

Choke:
- X_1—United Transformer Corp. UTCR-16

Tubes:
- V_1—7F8
- V_2, V_3—7N7
- V_4—7Y4

the condition of maximum setting on the gain control. It will be noticed that, because of the nature of the biasing of the first amplifier tubes, the gain diminishes rapidly when an input signal of over 0.15 mv. is employed. This helps obtain stability and tends to prevent shunting in the control operation.

It should be emphasized at this time that the magnetizing coil in the synchronous vibrator must be energized by a voltage which is synchronous and in phase with the supply voltage to the leading tube in the CR7503-A125. The reason for this becomes evident in the discussion of the biasing arrangements.

THE DESIGN OF THE BIASING ARRANGEMENTS

Figure 7 shows an idealized version of the voltage relationships establishing an unbalance voltage calling for heat in the specimen, and the idealized application of this voltage to provide current flow to produce that heat. All voltages indicated in the upper portion of the diagram are referred to positions in a simplified schematic of the control circuit. Voltages of positive sense are indicated upward; of negative sense, downward, but are not necessarily drawn to scale. Horizontal displacement indicates the passage of time, the time interval shown being of the

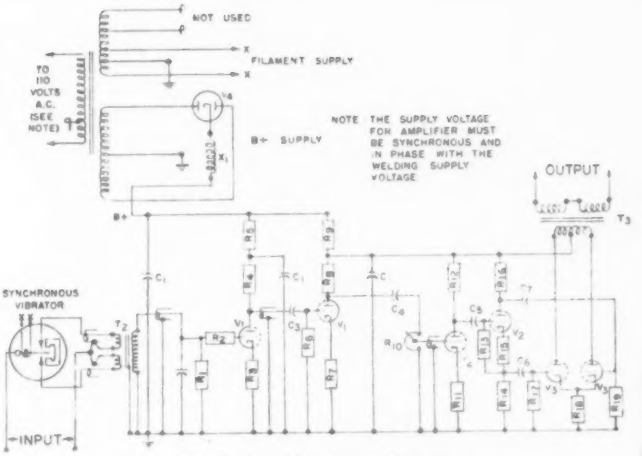

NOT USED
FILAMENT SUPPLY
TO 110 VOLTS A.C. (SEE NOTE)
B+ SUPPLY
NOTE THE SUPPLY VOLTAGE FOR AMPLIFIER MUST BE SYNCHRONOUS AND IN PHASE WITH THE WELDING SUPPLY VOLTAGE
OUTPUT
SYNCHRONOUS VIBRATOR
INPUT

Fig. 9 Amplifier circuit diagram

order of 450 electrical degrees, or approximately $^1/_{50}$ sec.

At the top of the diagram, Fig. 7, the relative values of E_1, the thermocouple output, and E_2, the output of the cam-controlled potentiometer, are shown, together with the small positive unbalance voltage, E_3, which is the resultant of $E_1 + E_2$. Immediately below is shown the nature of the a.-c. unbalance signal E_3', appearing at the input to the voltage amplifier as a result of the action of the synchronous vibrator.

Notice that this voltage signal is in phase with the voltage E_A, appearing on the anode of the leading tube of the A125 Spot Welding Control. That is to say, the value of the unbalance signal voltage is of a positive sense when the anode voltage of the leading tube of the A125 is of a positive sense, and conversely. The value of E_A as a function of time is indicated as a dashed line, referred to the horizontal axis near the center of the figure.

The amplified unbalance signal, E_3, is here indicated by the solid line, of the same form and phase as E_3', but of greater magnitude. It will be noted that this voltage wave is not symmetrical about the time axis, but is displaced in the negative sense by an amount E_4, called the d.-c. holdoff bias.

This negative holdoff bias is supplied by a 22$^1/_2$-v. bias battery in series with the lead connecting the amplifier to the cathode circuit of the A125. The bias voltage tends to force the cathode 22$^1/_2$ v. positive with respect to the zero signal voltage on the grid. Since the firing characteristics of the thyratron tube are such that initiation of the flow of anode

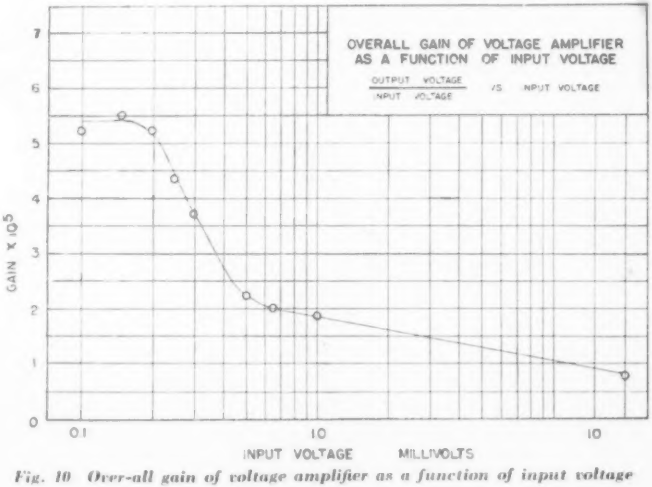


Fig. 10 Over-all gain of voltage amplifier as a function of input voltage

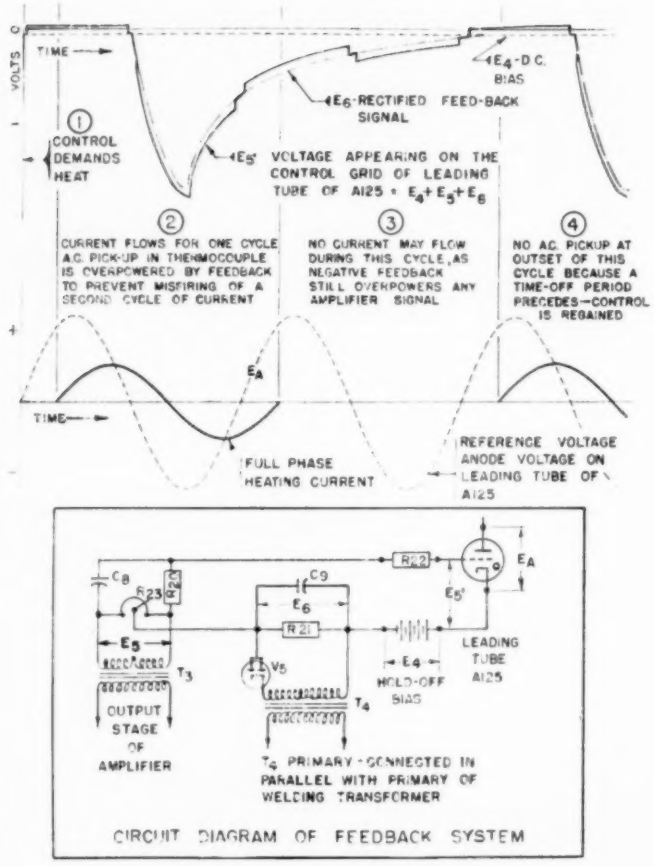

VOLTS
TIME
E_4-D.C. BIAS
E_6-RECTIFIED FEED-BACK SIGNAL
1 CONTROL DEMANDS HEAT
E_5' VOLTAGE APPEARING ON THE CONTROL GRID OF LEADING TUBE OF A125 = $E_4+E_5+E_6$
2 CURRENT FLOWS FOR ONE CYCLE A.C. PICK-UP IN THERMOCOUPLE IS OVERPOWERED BY FEEDBACK TO PREVENT MISFIRING OF A SECOND CYCLE OF CURRENT
3 NO CURRENT MAY FLOW DURING THIS CYCLE, AS NEGATIVE FEEDBACK STILL OVERPOWERS ANY AMPLIFIER SIGNAL
4 NO A.C. PICKUP AT OUTSET OF THIS CYCLE BECAUSE A TIME-OFF PERIOD PRECEDES—CONTROL IS REGAINED
E_A
TIME
FULL PHASE HEATING CURRENT
REFERENCE VOLTAGE ANODE VOLTAGE ON LEADING TUBE OF A125
C8
R23
R22
C9
E_6
R21
R2
E_A
E_5'
E_5
T_3
V_5
E_4 HOLD-OFF BIAS
LEADING TUBE A125
T_4
OUTPUT STAGE OF AMPLIFIER
T_4 PRIMARY CONNECTED IN PARALLEL WITH PRIMARY OF WELDING TRANSFORMER
CIRCUIT DIAGRAM OF FEEDBACK SYSTEM

Fig. 11 Circuit diagram of feedback system

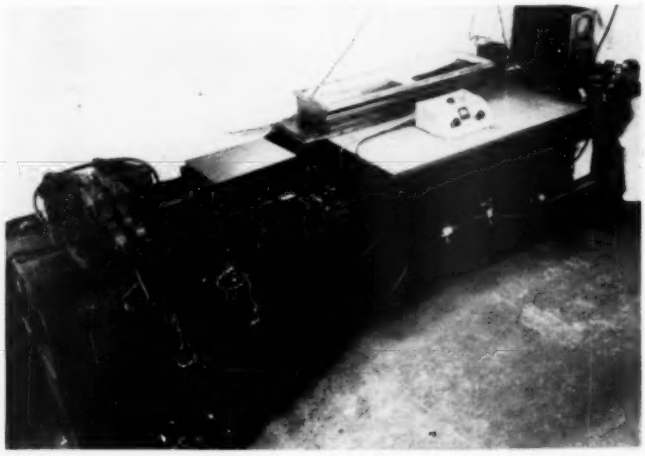


Fig. 12 General view of control device

current may not occur so long as the grid is maintained at a lower potential than the cathode, the d.-c. holdoff bias prevents accidental flow of anode current in the leading tube. However, an unbalance signal, E_5, of as little as 0.05 mv. produces an amplified signal, E_5', of approximately 26 v., which is sufficient to drive the grid positive. If the grid is driven positive at the same time the anode of the leading tube is positive with respect to its cathode full anode current will flow. The conduction of anode current continues only as long as the anode remains positive, i.e., $\frac{1}{2}$ cycle, and then control of the tube is regained.

The circuit of the CR7503-A125 is so designed that, whenever the leading tube conducts, the trailing tube conducts during the next consecutive half cycle. The leading and trailing tubes therefore act as an electronic contactor, permitting instantaneous on-off control.

Figure 8 shows the voltage relationships establishing an unbalance signal indicating that the specimen temperature is above correspondence. It will be noticed that the voltages E_5' and E_5 are now both 180 electrical degrees out of phase with the anode voltage E_A. This condition never allows the grid and anode of the leading tube to be positive with respect to the cathode at the same instant, and, therefore, prohibits the flow of anode current in the leading tube. This in turn prevents firing the second, or trailing, tube and the electronic contactor presents an open circuit in the path of the anode voltage.

The firing pattern of the main ignitron contactors is determined by the firing pattern of the leading trailing pair; and since the ignitrons serve to control the current in the welding transformer primary, their firing pattern in turn determines the flow of current in the specimen. The flow of current in the specimen influences the temperature of the specimen, which in turn influences the original unbalance signal, and so on.

Unfortunately, simple d.-c. bias was found to be insufficient to insure consistent operation. Stray pickup voltages arising in the thermocouple circuit were superimposed on the desired unbalance signal, were amplified and were injurious to the proper operation of the control. The behavior of the control under such conditions was very unreliable, since the effect of the pickup voltage on the control operation depended on the magnitude and phase of the pickup voltage relative to the unbalance signal. The relative magnitude and phase of the pickup voltage, in turn, depended on the positioning of the thermocouple and the magnitude of the heating current in the specimen. Two forms of unwanted pickup signals were found to be present:

1. A pickup signal induced in the leads of the thermocouple in the vicinity of the specimen by the action of the heating

current. The flow of current in the specimen establishes an alternating magnetic field which links the thermocouple loop, and thus induces a voltage in the thermocouple which is proportional to the heating current.

2. A second pickup signal more closely resembling a direct voltage pickup as a result of the connection of the thermocouple with the specimen.

Since both forms of pickup were found to be present only when heating current was flowing through the specimen, an obvious solution presented itself. If the heating current were interrupted for a short time periodically, the unbalance signal could direct the control operation at the end of each of these short times unimpeded by the presence of pickup voltage. Figure 11 shows the details of the system finally evolved for accomplishing this.

The schematic diagram of the feedback bias system is shown at the bottom of Fig. 11, together with the location of the voltages to be referred to in the discussion of the circuit operation. A list of circuit components will be found in Table 2.

Transformer, T_4, is the feedback transformer, and is connected in parallel with the primary of the welding transformer. During each cycle when voltage is applied to the primary of the welding transformer, a rectified current flows through the circuit consisting of the secondary of T_4, R_{21} and the half wave rectifier V_5. This results in charging the capacitor C_1, in parallel with R_{21}, to a peak voltage of 840 v., with the positive side toward the cathode of the leading thyratron in the A125. This effectively causes the grid of the leading tube to be driven negative with respect to the cathode, as indicated by the voltage curve, E_6, (at top Fig. 11), the peak value being 840 + $22^1/_2$ or $862^1/_2$ v. negative. As may be seen by reference to Fig. 11, this leaves the grid voltage, E_5' (which is the algebraic sum of E_4, the d.-c. bias; E_6, the feedback voltage; and E_5, the amplifier output signal) highly negative with respect to the cathode during the next positive half cycle of the anode voltage, E_A, on the leading tube, and prevents firing at this time. Since the leading tube is not able to fire, current may not flow in the specimen during this cycle. The voltage E_6 is meanwhile decaying exponentially with a time constant of 0.008 sec. (or about $^1/_2$ cycle) as a result of the discharging of C_9 through R_{21}. By the time the anode voltage, E_A, on the leading tube, again becomes positive, the grid bias has returned essentially to normal (i.e., equal to E_4, the d.-c. bias) and control by the amplified unbalance signal is regained.

As may be seen by inspection of Fig. 11, the critical period, during which pickup might interfere with the operation of the control, occurs during the last portion of the negative half cycle of heating current. During this period, the anode voltage on the leading tube of the A125 has just become positive, and the tube would therefore fire if the pickup signal were such as to drive the grid positive. The extremely great negative bias voltage is employed during this period to insure against any possibility of the amplified pickup voltage causing misfiring. The short time constant is necessary to provide the quick recovery of normal control operation (i.e., after only one cycle time-off). Although the use of this system obviously means that, regardless of demand, two consecutive cycles of heating

Table 2—Circuit Constants for Feedback Bias Circuit Shown in Fig. 11

Transformers:
- T_3—Thordarson T19 D03 shown with amplifier
- T_4—440-v. primary, 600-v. secondary } feedback transformer

Resistors:
- R_{20}—100,000 ohms, 1 w.
- R_{21}—32,000 ohms, 1 w.
- R_{22}—240,000 ohms, 2 w.
- R_{23}—15,000 ohms, potentiometer

Condensers:
- C_8—0.01 mf., 1000 v. d. c., Pyranal
- C_9—0.25 mf., 1000 v. d. c., Pyranal

Tubes:
- V_5—6 x 5

Fig. 13 View of associated control equipment

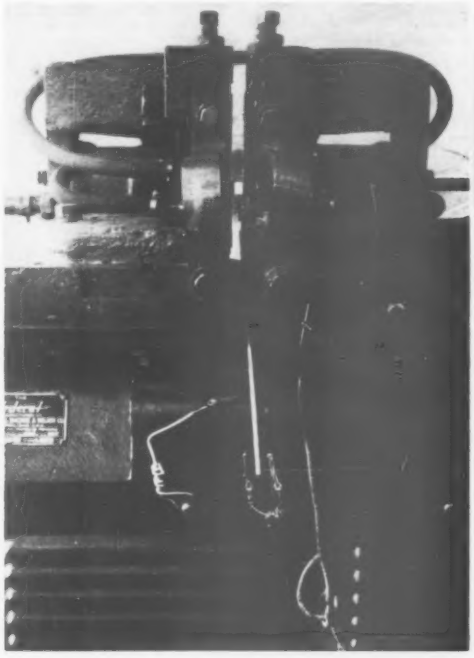


Fig. 14 Closeup of flash welder, showing specimen

current may not flow, the loss in rate of heat input may be compensated for by an increase in the magnitude of the heating current.

The phase-shifting network, shown at the left side of the schematic in Fig. 11, is used to compensate for minor phase shifts occurring in the amplifier, and is not of significance in the operation of the feedback network. Rather, it serves to adjust the phase of the firing signal from the amplifier to exactly match the phase of the anode voltage, E_A.

INTERCONNECTIONS

The actual interconnections in the design of the control circuit are unnecessarily complicated by the fact that many previously made interconnections between existing equipment had to be retained in operative condition. This situation, however, once accommodated, had little bearing on the operation of the equipment.

The essential details of interconnection involve:

1. Electrostatic shielding of all interconnecting leads.

2. A switching arrangement to permit recording the output of the cam-controlled potentiometer on an Esterline Angus Graphic Milliammeter using a General Electric Photoelectric Potentiometer.

3. A switching arrangement to permit feeding a small d.-c. voltage of known magnitude directly into the input of the synchronous vibrator, in order to check the sensitivity of the over-all system to small changes in input voltage.

4. A minor change in the wiring of the leading tube in the G-E CR7503-A125 Spot Welding Control. This change merely substituted the control signal voltage, E_b' (see Fig. 11), for the signal from the timing tube, usually connected at the grid of the leading tube in the A125.

5. The General Electric D160 Current Regulator Control and the associated General Electric F170 Program Control are connected in the usual way in the grid circuit of the main firing tubes of the General Electric CR7503-A125 Spot Welding Control.

6. A Brush Direct Inking Recording Oscillograph is suitably connected to record the current flowing in the primary of the welding transformer. This instrument was used primarily as a check of the operation of the control device, since the actual current magnitudes used are of no practical value.

7. A cathode-ray oscilloscope was connected across the output of the control circuit between the grid and cathode of the leading tube of the A125. This permitted a continuous visual check of the instantaneous magnitude of the amplified unbalance signal, and thus of the over-all operation of the control.

8. The amplifier chassis and potentiometer frame were carefully grounded.

Figure 12 shows a general view of the control device. The flash welder is located at the left, and the thermocouple leads may be seen connected to the clips on the terminal board at the front. The cam-operated potentiometer, and adjusting rheostats are located on the left half of the table. In back at the right may be seen the cathode-ray oscillograph, and in front of it the feedback network and amplifier. Underneath the table at the right are the photoelectric potentiometer and recording milliammeter, while at the left underneath the table is the energy storage unit for welding the thermocouples in position.

Figure 13 shows the other associated equipment. At left in the foregound is the General Electric CR7503-F170 Program Control. The safety switch and initiating switch are located on the top of the small control box on the front left corner of the table in the foregound. In the center of the table are the Brush recording oscillograph and associated amplifier. The General Electric CR7503-A125 Spot Welding Control is located at the left end of the control panel in the middle background, with the General Electric CR7503-D160 Current Regulator Control mounted in the square panel on top. In the background may be seen the switch gear for the motor generator which supplies power to the equipment.

Figure 14 is a close-up of the flash welder showing a specimen in position in the jaws of the welder being heated by the control device. The thermocouple may be seen protruding from the jaws of the flash welder in its insulating tubing, with

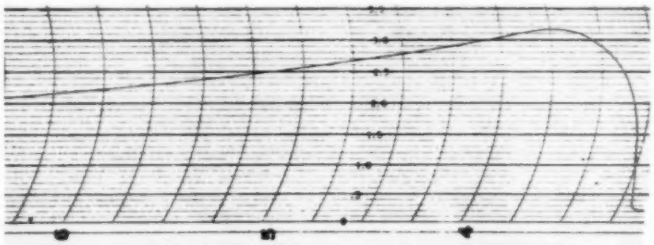


Fig. 15 Record of reference voltage produced by cam-operated potentiometer, recorded on Esterline Angus Graphic Milliammeter

Horizontal axis represents time, increasing to left. Vertical displacement is proportional to reference voltage in millivolts

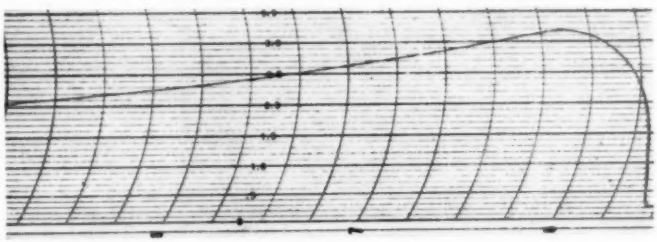


Fig. 16 Record of time-temperature cycle produced in specimen during cam output shown in Fig. 15 as reference voltage

Horizontal axis represents time, increasing to left. Vertical displacement is proportional to temperature in millivolts

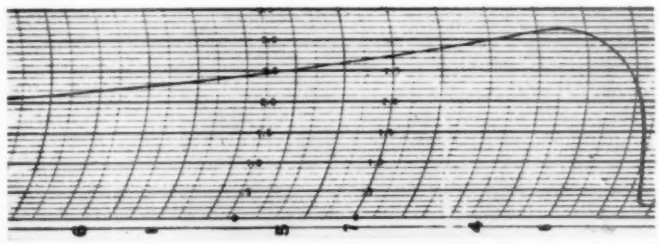


Fig. 17 Records shown in Fig. 15 and Fig. 16 superimposed and printed simultaneously for purpose of comparison

the free ends in the clamps on the terminal board at the front.

PERFORMANCE

Figure 15 shows a typical record of the output of the cam-operated potentiometer. Figure 16 shows a record taken of the output of an extra thermocouple placed in the specimen approximately 0.2 in. from the control thermocouple and in the same plane (taken perpendicular to the axis of the specimen). As may be seen in Fig. 17, when superimposed the curves are identical in so far as may be seen, with the exception of the first fraction of a second of time. Repeated checks of this type indicate an excellent degree of reproducibility with an error too small to be indicated on the measuring equipment used. A temperature gradient is known to exist longitudinally along the specimen, but over a region of approximately 0.20 in., parallel to the axis, the temperature difference observed amounted to approximately ±10° F. under operating conditions. The actual value of the gradient is dependent on the distance of jaw separation and the temperature of the specimen. However, the reproducibility of the time-temperature cycles, and the region of uniformity of the temperature seem to be ample to fill the purpose for which the machine was intended.

Checks were made periodically of the sensitivity of the control device by measuring the smallest d.-c. input voltage which, when introduced at the input to the amplifier, caused on-off control of the system. The results of these sensitivity checks indicate that an unbalance signal of 0.07 mv. is sufficient to operate the control. Converted to temperature changes with a chromel-alumel thermocouple, this would correspond to a change of ±3° F., or a sensitivity of about 6° F. in all control positions. This is borne out by observation of the magnitude of the amplified error signal during operation, as observed on the cathode-ray oscilloscope. By comparison with the amplified signal produced by known calibration signals, the magnitude of the instantaneous unamplified unbalance voltage could be ascertained. Under typical operating conditions the amplified signal corresponded to an unbalance signal of less than 0.1 mv. (4° F.) at all times.

As a further check of the operation of the control, records of the heating current pattern were made during each run by means of the direct-inking oscillograph. Figure 18 shows a typical record of the firing pattern for a satisfactory run. It will be noted that the pattern is quite regular with no evident periods of misfiring. Figure 18 shows also a typical pattern obtained when the control was functioning improperly as a result of stray voltage pickup in the thermocouple leads or insecurely welded thermocouples. A noticeable bunching of the firing record followed by periods during which no current flowed is characteristic evidence of improper operation.

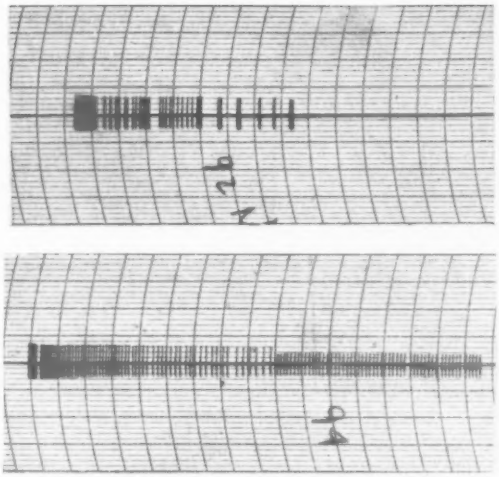


Fig. 18 Records taken with brush direct-inking oscillograph

(Upper) Improper operation. Erratic firing pattern. (Lower) Proper operation. Regular firing pattern

The control equipment was found to satisfy all of the original requirements as stated in the Object and the Scope sections of this report. Checks have indicated a maximum obtainable cooling rate in the neighborhood of 330° F. per second at 1300° F. when a jaw separation of 0.4 in. was employed. No data are available on the maximum heating rate, but it is known to be in excess of 2500° F. per second.

RECOMMENDATIONS FOR FURTHER WORK

1. Construction of a high-gain d.-c. amplifier to permit elimination of the synchronous vibrator. A circuit has been advanced by Moyer of the Electrical Engineering Dept. at Rensselaer Polytechnic Institute as suitable for this purpose. Trouble has been experienced throughout the preparation of this paper, due to phase restrictions imposed on the over-all circuit by the use of the synchronous vibrator. Furthermore, it appears that the problems arising from pick-up in the thermocouple leads would be more readily overcome if the synchronous vibrator were eliminated.

2. Further work should be done to modify the design of the cam-operated potentiometer to permit the reproduction of more rapid cooling cycles. While the present design of the control permits rapid cooling of the specimen, the present cam-operated potentiometer will not establish the reference voltage for such rapid cooling cycles. This is attributed directly to the mechanical difficulty experienced in making the cam follower track the steep cam required.

A possible solution would appear to be the utilization of a photoelectric tracking device which would require no mechanical contact with the cam. Such equipment, designed for contour-following operations is commercially available, and could be adapted to suit the needs of the control equipment.

ACKNOWLEDGMENT

This program, approved and guided by the Weldability Committee, was financially supported by the Welding Research Council of the Engineering Foundation until February 1949. From February to June 1949, the program continued as a subject of a Master's Thesis by Warren F. Savage.

Bibliography

1. Hess, W. F., Merrill, L. L., Nippes, E. F., Jr., and Bunk, A. P., "The Measurement of Cooling Rates Associated with Arc Welding and Their Application to the Selection of Welding Variables," The Welding Journal, **22** (9), Research Suppl., 377-s to 422-s (1943).

2. Jackson, C. E., and Goodwin, W. J., "Effect of Variations in Welding Technique on the Transition Behavior of Welded Specimens," Part II, *Ibid.*, **27** (5), Research Suppl., 253-s to 266-s (1948).

3. Nippes, E. F., Merrill, L. L., and Savage, W. F., Cooling Rates in Arc Welds in 1/4-In. Steel Plate," *Ibid.*, **28** (11), Research Suppl., 556-s to 564-s.

Appendix I

SUMMARY OF DATA USED FOR FIG. 1

Values of $F(s, d)$ Taken from Table 3(A), at distance from Weld Center Line in Inches

Time, sec.	*0.32*	*0.35*	*0.40*	*0.50*	*0.60*	*1.0*	*1.20*
2	27.50	19.65	12.90	7.17	4.5	0.2	0
5	36.50	29.30	21.64	13.68	9.36	1.65	0.18
10	26.24	24.32	21.24	16.20	12.30	3.96	2.16
40	15.58	15.21	14.55	13.17	10.90	8.52	7.26
180	7.61	7.52	7.35	7.00	6.45	597	5.85

Values of T, the plate temperature, obtained by solving equation

$$T - T_0 = \frac{F(s, d)}{1000} \times \text{Energy input} \times \text{Input factor} \qquad \text{(II)}$$

where
$T_0 = 72°$ F.
Energy input = 70,000 joules per inch
Input factor = 1.0
are tabulated below.

Values of Temperature, °F., at Distance, from Weld Center Line in Inches

Time, sec.	*0.32*	*0.35*	*0.40*	*0.50*	*0.60*	*1.0*	*1.2*
2	1999	1437	973	575	387	84	72
5	2630	2122	1602	1028	722	187	85
10	1910	1770	1562	1170	932	449	223
40	1160	1137	1090	992	834	669	581
180	605	598	587	562	524	490	481

Figure 1 (text) was obtained by plotting the above values of time and temperature for the tabulated distances from the weld center line.

Fun, Facts and Fancies About Research

What is this thing called research? A down-to-earth profile helps explain

by K. W. Miller

"Many a truth is spoken in jest."

AMAZED by the achievements of science during and since the war, people have become research conscious. Yet there is much general misunderstanding as to what research really is, its objectives and methods, its limitations, as well as its possibilities.

What then is the nature of this modern genie, this modern god or beast known as "research"? Research is a human enterprise, and as such partakes of all the trials and joys, satisfactions and disappointments, gloom and humor—in short, all the serious and frivolous aspects typical of any human endeavor. If we abandon sterile technical jargon and get down to earth where the researchers live and work, we are sure to find things to inform, interest and even amuse us—a blend of the sublime and the ridiculous. Since the area covered by research is so vast, we will restrict our exploration to industrial research, with examples as exemplified in a large independent research organization such as Armour Research Foundation of Illinois Institute of Technology, excluding in particular, medical, social or economic research.

Shakespeare has depicted the seven ages of man—the glorious rise and then the sorry decline. As yet, for men collectively, research is the present intermediate stage in a thus far unreversed human progression.

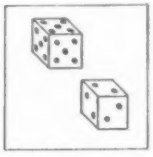
K. W. Miller is Assistant Director of Research, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

Man ever proceeds from vagueness to precision, from the particular to the general and from the concrete to the abstract. From guttural sounds to the written alphabet was a tremendous advance, but man did not stop there. Letters of the alphabet, typified by S, were given still more abstract significance by the Greek symbol Σ, which in high-school algebra we learned to use as a sign of summation. Later, in college, we learned to modify the symbol S to the integral sign, $\int$, for highly sophisticated use in calculus.

Meanwhile, in other pursuits, man was progressing from barter to the use of money and credit. The dollar sign, $, for money is now a highly important and familiar (sometimes abstract) symbol to all of us. Now in the last few years, man has learned to combine these two streams of progress into research—the marriage of science and industry—with truly remarkable consequences.

Research is big business. In a comparatively few years, research has grown from almost nothing to a multimillion dollar industry. Big corporations have split off or established large research divisions—frequently separately housed in large buildings and staffed, equipped and administered apart from production operations. Several industrial research institutes have grown to operate with multimillion dollar annual budgets. New ones are being organized and started almost every year. Recently, also, Government has undertaken research in a big way.

Research is a gamble, a game in which everybody cheats and everybody wins. It is a game played against the restrictions of physical nature and the prejudices and shortcomings of human nature. It is a game of both luck and skill, but it is possible to play with marked cards and dice loaded in your favor, and to follow a "system" that shifts the odds definitely in your favor.



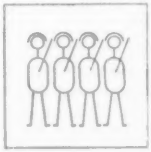
Every true research project is a gamble (otherwise it would be only an engineering application). It contains, entirely or in part, unknown elements to find or explore. Any given research project may be a failure; however, by knowing and applying the "rules" of this fascinating game, the odds for success are overwhelming in the aggregate, taken over a period of time, or over many research projects. The phenomenal recent development of industry in this country is evidence of this.

It is the method and spirit of research more than the people who play it that count. Probably, several other countries have as great natural resources and as many individuals with as high I. Q.'s as we do; but they have not, as yet, developed our proficiency in this exciting industrial research game. Were it not for the fact that everybody wins and nobody loses in the long run, playing this one-sided gamble of research would be definitely unsportsmanlike. However, let no individual or company be deceived about all this. The ante is high and success in any particular research project uncertain. Those wise in the ways of research do not expect to advance just a few dollars, then pull that marvelous handle called "research" and immediately hit the jackpot.

Research is good fun. It contains all the elements of good sport: luck, skill, uncertainty, failure and rich reward. Physical nature contains limitless "tough nuts to crack" and is forever springing unexpected surprises on those who match wits against her. Natural science is difficult, mysterious, deceptive, fascinating, and coy by turns; but, understood and harnessed by industrial research, it opens new avenues to progress and supplies the power and understanding to travel them.

Research is exciting adventure. Columbus sought a new route to India and discovered, instead, a new continent. So in research, it often happens that while conducting research toward a particular objective useful by-products turn up—sometimes more valuable than the original goal sought. Even an outright "unsuccessful" research project must be very badly handled or bungled not to yield much valuable training and considerable useful information along the way. Good research men probably learn as much from their failures as from their successes, just as an occasionally defeated good general respects, studies and learns from a skillful foe.

Research is regimentation. This thought may surprise you and may be distasteful, for, by temperament, scientists and engineers are the most individualistic, independent people on earth. It is the fundamental particles of nature, however, which are being regimented—electrons, atoms, nuclei, etc.—and we, the research scientists and engineers, are doing the regimenting. *We* are the polit-bureau! By purges, we purify materials to contain molecules all of one kind. By electric and magnetic fields, or other means, we indoctrinate electrons and atoms to a common orientation exhibiting unique properties, such as magnetism or optical polarization. By fearful means and diabolical contrivances, we impel electrons or molecules into conformity with uniform velocities as streams in our electron tubes, cyclotrons, turbines and jet engines. We use catalysts as subversive influences, propagandizing atoms and molecules into particular chemical behavior or union and we force them to labor in our prison camps of test tubes or pilot plants.



Everything we do can be resolved into some form of regimentation of particles. Ruthlessly, we impose our will on nature. Yes, we must admit it—we are very clever dictators. However, we do encounter rebellions and revolutions in the form of apparatus failures, explosions and spoiled experiments; and it yet remains to be seen whether, in the creation of the atom bomb and bacteriological warfare, we have overdone our cleverness.

Research and the accumulation of useful knowledge is like pouring water slowly onto a dusty floor. Like the water, accumulated knowledge and scientific-technical "know how" continuously spreads over a larger and larger area. Advance tentacles of pure, basic or fundamental research push ever forward, sometimes rapidly, sometimes haltingly, often converging and meeting again on common ground. Unexplored islands are left behind, but those eventually are closed up. "Nothing succeeds like success" and the larger the area already covered, or the facts now known, then the greater the power, imagination and facilities available to make still further advances.

The stock pile of fundamental research facts will never be "used up." Newton's laws of motion, Maxwell's electromagnetic equations, Einstein's theory of relativity and many other scientific achievements will always be useful in practical technical human affairs; and, no matter how modified in detail or supplemented by other new fields such as nuclear physics, old scientific facts will continue to be necessary, ever useful and constantly used. Researchers, however, are justifiably concerned with enlarging the foundations by still more fundamental research as they contemplate an ever-growing superstructure of applied and industrial research. And, incidentally, much of modern industry is founded on fundamental or "pure" research in mechanics, chemistry, physics, mathematics, etc., "handed to it on a silver platter" literally, without industry itself paying out a dime.

For selfish reasons, if not reasons of equity, industry owes it to science to "put something back into the pot." This can take the form of financing training of research workers or support of fundamental research as such or at least, the maintenance of a broadminded and progressive attitude toward research. This means including basic as well as applied phases in industrial research programs, whether such are conducted in the company's own laboratories or farmed out to universities or research institutes. Many industries have done, and are doing, one or more of these things to promote fundamental or pure research.

We proceed now to consider the objectives, means and methods of research. Our remarks will be directed more particularly to activities in a large industrial research foundation. We shall omit much reference to the administrative policies and procedures which in a large research organization are not very different from good practice in successful business organizations. Although the particular modifications are important, this is much too large a subject to consider here.

The objectives of industrial research are well known, but it is desirable to restate them here. Broadly, they may be listed as:

(*a*) Improvement of present processes or products.
(*b*) Development of new processes or products.
(*c*) Utilization of wastes or improved markets for by-products.
(*d*) Elimination or reduction of rejects or processing difficulties.
(*e*) Reduction of costs.
(*f*) Promulgation of a progressive, alert attitude upon all members of the company's organization (not to mention its management).
(*g*) Miscellaneous.

For a single industry with one or a few products, the research problems, though varied, might be described as "homogeneous," or directed to limited coverage of one (or at most only a few) end products. With an industrial research institute or foundation such as Armour Research Foundation, on the other hand, the objectives and subjects investigated for many sponsors are, in the aggregate, highly random and unrelated.

This wide variety has both advantages and disadvantages from the standpoint of administration and quality of services rendered. For Armour Research Foundation, it necessitates three major organizational divisions

(*a*) Research
(*b*) Magnetic Recorder
(*c*) International

The first, by far the largest, is subdivided into six major research departments:

(*a*) Physics
(*b*) Metals
(*c*) Chemistry and Chemical Engineering
(*d*) Applied Mechanics
(*e*) Electrical Engineering
(*f*) Minerals and Ceramics

These departments are in turn comprised of groups (e.g., optics, acoustics, spectroscopy, magnetism, etc., in the Physics Department) and each of these is still further subdivided into small working subgroups on individual research projects. One is irresistibly reminded by all of this of the verse:

> "The little fleas have lesser fleas
> Upon their backs to bite 'em
> And these in turn still lesser fleas
> And so ad infinitem."

The difficulties of housing, equipping, staffing and administering a wide diversity of subject matter and sponsors' objectives are obvious. On the other hand,

the presence of an almost complete variety of apparatus and diversity of staff aptitudes and training makes possible the undertaking of almost any research problem. By mutual advice and cross-fertilization of ideas between staff members—the "Armour Plan" of cooperative research—we can bring to bear an almost irresistible cooperative power and breadth of knowledge and viewpoint to any tough research problem. Not only that, but the variety of subject matter is highly stimulating to the staff; it prevents us from becoming stale and broadens our abilities generally.

Years ago I lived in a very small Mississippi community clustered around a railroad station whose water tank facilities afforded excuse for a train or two a day to stop there. While waiting for the daily "number nine" it was the custom of the man who served as combination station, freight, ticket and express agent and telegraph operator, to while away the time shooting craps with the local expert who had had riverboat gambling experience. The competition was too keen, and there was a constant turnover of station agents. Nevertheless, one did remain an unusually long time, although apparently no more successful with the dice than his predecessors. One day, after an unusual run of bad luck, this agent excused himself from the group for a moment and returned from the station with a fist full of cash, and with the remark, "you may be able to beat me, but you can't beat the American Express Company!" Shortly thereafter, an auditor came around and there was still another new face in the station master's job.

This melancholy tale points a moral for research which the unfortunate station agent discovered years ago. You can beat any one individual in research problems, but a composite group as a whole, such as the Armour Research Foundation staff, is almost (but, of course, not always) unbeatable. The large variety of available research equipment with skilled experts in correspondingly diverse scientific fields to manipulate it and to interpret the findings, is a tough combination to beat.

Beyond doubt, the most important single asset of a research institute is its staff. Outstanding experts in a wide variety of scientific and technical specialties cannot be assembled in a short time (except, of course, by government edict). Moreover, it takes time for a group of experts to learn each other's particular aptitudes and personalities and to achieve harmonious and effective cooperation. But a good staff, once established and constantly improved in size and quality by careful selection of each additional recruit, becomes an invaluable part of a research institute. Mutual association and joint research endeavor with such a group is a most pleasant and intellectually stimulating experience.

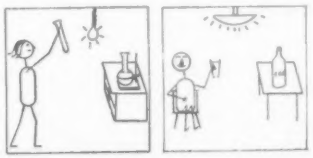
In procuring and retaining high quality research personnel it is important that their morale be maintained at a high level. In addition to adequate salaries, capable attractive secretaries and pleasant working conditions, recognition for meritorious professional accomplishment is an important item. This may be accomplished in large part by encouraging staff members to write papers and give talks, to participate actively in scientific and technical societies, and to attend conventions in fields of their special interests.

Industrial research institutes, such as Armour Research Foundation of Illinois Institute of Technology, have only indirect control in the selection of the problems they undertake. So long as research problems available and offered exceed capacity to undertake them, it is possible to exercise considerable selection in the problems accepted. This is done in our organization by a special Project Clearance Committee, which carefully considers every proposal to a prospective sponsor before it is released. The major items considered are our ability to provide adequate space, equipment and staff, the suitability of the problem to our technological growth and prestige, and whether we feel that the problem can be successfully solved, or at least that we can contribute significantly to progress on it. This protects our sponsors as well as ourselves, for although some errors may be made in such preliminary analyses, obviously, with more research to be done than there are facilities available, it is only common sense to undertake the most important and potentially successful projects first.

Our Foundation is not endowed and, operating as it does on a nonprofit basis, it has no large fund of money for self-supported fundamental research programs. Nevertheless, it carries on continuously several such projects based on the best ideas submitted by the research staff. Occasionally some of these projects develop to such importance that they are taken over and further developed by outside industrial sponsorship.

Several of these Foundation-sponsored projects are devoted directly to the public interest. Among these may be mentioned our Registry of Rare Chemicals, our Dust Abatement and Noise Abatement surveys in the city of Chicago, and our assistance to medical research at a large Chicago hospital. In addition, we sponsor regular conferences on broad technical subjects of ultimate value to the public at large.

Perhaps at this point the reader will be impatient for a description of just exactly how research actually *is* conducted. A popular impression engendered by magazine advertisements is one of a white-frocked, professional-appearing individual holding up a test tube to the light for inspection (not to be confused with that familiar "man of distinction" with an up-raised whiskey glass in his hand). Another popular concept is re-



Man of Research *Man of Distinction*

search "magic," or again, that astonished chemist,

dumbfounded at the silhouette he has produced behind that translucent new plastic shower curtain! These pictures, with a proper background of mysterious chemical flasks, electronic gadgets and perhaps a few cogwheels here and there, do bear some remote resemblance to research in so far as skillful manipulation of scientific apparatus is concerned. However, they do *not* convey the essence of the matter, the *mental activity*.

The Thinker

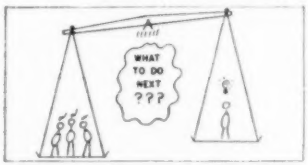
The able mathematical analyses, the careful, laborious technical thinking and planning, the acute observation of results for the otherwise overlooked phenomena that may be the key discovery of the experiment, the tedious correlation of data and the spark of intuition or hunch (perhaps conceived while shaving) and fertile suggestions growing out of joint discussions with associates (often at the lunch table); all of these are the true attributes of research. Research is method, *an attitude of mind;* the apparatus are just the "props," necessary to the show but inert and useless without the actors.

There is much value and effectiveness in the Edison-Kettering empirical type of research, and it is possible to cite many spectacular examples of how the pure experimenter has confounded theoretical expectations. Doubtless, research will always retain a large element of experimental "cut and try" or "ascertaining by finding out." Abe Martin spoke rare truth when he said, "It is remarkable how a few facts will break up an argument."

However, theoretical science is advancing at a tremendous rate. A properly trained research staff can predict with increasing assurance what materials, methods or processes are most likely to be successful in solving a particular problem, or conversely, what the probable result of particular experiment will be—not always, of course, but as often as not. The permutations and combinations of essential factors in research problems are becoming so large that the purely empirical Edisonian experimental approach alone would be intolerably costly, time consuming and wasteful.

Research, at present, consists of a blend of the two procedures, a judicious mixture of theoretical analysis and experimental trial, of relentless reason and of gifted intuition. A modern research staff consists of personnel who are applied mathematicians, trained physicists, chemists, mechanical and electrical engineers, metallurgists, ceramists, etc., and also highly skilled experimenters or manipulators of apparatus. Sometimes two or more of these aptitudes are combined in one man, but the important point is that the research staff as a whole should comprise a rich variety of skills, aptitudes and fields of specialty, and a wide diversity of training. Then the "Armour Plan" subjects, at the crucial stages, every difficult research problem to any or all available technical talent on the staff that might contribute to the solution.

It is a difficult problem, indeed, that can withstand for long such a powerful cooperative attack. Few modern complex problems are solved by a single "flash



of genius," but mutual cooperation of several bright minds brings sparks of inspiration here and there until, combined and fanned into flame by team enthusiasm, the joint attack becomes as irresistible as a forest fire sweeping all before it.

"Gold is where you find it"; likewise, good research ideas. We are repeatedly pleasantly surprised to find that a research problem in one department exists already virtually solved in another department. It is a good deal like the Acres of Diamonds story, so we have learned to look in our own back yard first—that is a part of the "Armour Plan."

Industrial research is a very large subject, which could easily extend over many printed pages. I have touched upon only a few high lights, which it is hoped have been of interest.

In these days of fast-moving science and technology, probably no research director, who is privileged to administer a large research organization of superbly talented scientists and engineers, does not at times feel bewildered in trying to keep abreast of technical developments, even in his own organization.

With humble philosophical humor, directors of research are disposed to sympathize with the rabble rouser of French revolutionary days, as related years ago by Dr. Mees. While this harassed individual (the rabble rouser—not Mees) was attempting to take wine, nourishment and a moment of ease at a sidewalk café in Paris, a crowd of people rushed by. He sprang to his feet and exclaimed, "There goes the mob! I must hurry up and follow them, for *I* am their leader!"

"Transition" Temperatures Under Various Amounts of Plastic Flow

The relationship of conditions approaching brittle transition temperature are compared with other methods of determining the so-called transition temperature

by N. Grossman and C. W. MacGregor

INTRODUCTION

THE method[1, 2] used at M.I.T. to determine the temperature of transition from ductile to brittle fracture is based upon the following definition of the brittle transition temperature. This is defined as the highest temperature under which no macroscopic plastic flow occurs when the special slow-bend test is conducted under fixed conditions of constraint and strain rate.

Various procedures are used in other laboratories in order to determine the transition temperature and usually considerable plastic flow is present in these tests before fracture takes place. Such methods involve the measurement of angle of bend, lateral contraction, energy absorption, cleavage to shear fracture ratio, etc. Almost all of these tests specify a temperature at which one of these criteria will be at an arbitrary value.

In order to determine the quantitative effect of prior plastic flow on such transition temperatures and to thus throw some light on the relation between the M.I.T. slow-bend test and others which are available, the authors were requested to undertake a brief investigation of this problem. For this purpose tests were performed on the same material as used at Lehigh University following different methods.

MATERIAL TESTED

Four hot-rolled steel plates, 3/4 in. thick were obtained from Lehigh University with the information as shown in Table 1.

The specimens were machined with the root of the notch perpendicular to the direction of rolling. Photomicrographs are shown in Fig. 1. The dimensions of the test bars are given in Fig. 2.

Table 1—Ladle Analysis

Code	*Deoxidation practice*	*C*	*Mn*	*P*	*S*	*Si*	*Grain size*
BF	Semikilled + Al in mold	0.18	0.73	0.013	0.030	0.06	5–7
BC	Semikilled	0.18	0.73	0.013	0.030	0.06	2–4
BH	Semikilled	0.18	0.50	0.014	0.027	0.08	2–4 with 25% 5–7
BL	Semikilled + Al in mold	0.15	0.47	0.014	0.035	0.09	5–7

TESTING EQUIPMENT

The special slow bend has been described in detail previously[1, 2] and only a very brief account of it is given herein. The testing equipment is designed to load a specimen in simple bending at a uniform speed and temperature and to supply a load-deflection record of the test. AB-7, SR-4 electric strain gages connected in a bridge circuit are used to measure both the load and deflection. The integral parts of the apparatus include the loading machine with strain gages, the thermocouple and millivoltmeter (calibrated to read ° F. directly) stop watch, electronic recorder and a still camera.

The loading device is a lever system which transmits the load to the specimen resting on suitable supports. The supports and specimens are housed in an Aminco "Sub-zero Test Cabinet." The interior of the cabinet can be cooled to about −100° F. by forced circulation of dry ice and the specimen can be further cooled to −320° F. by pouring liquid nitrogen around it.

The time of testing is measured either by the electronic recorder which places a "dot" on the load-deflection record at regular time intervals, or by a stop watch at the slower speeds.

An a.-c. bridge system is employed whereby a 5500-cps. voltage is introduced into the load bridge and

N. Grossman and **C. W. MacGregor** are associated with the Dept. of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

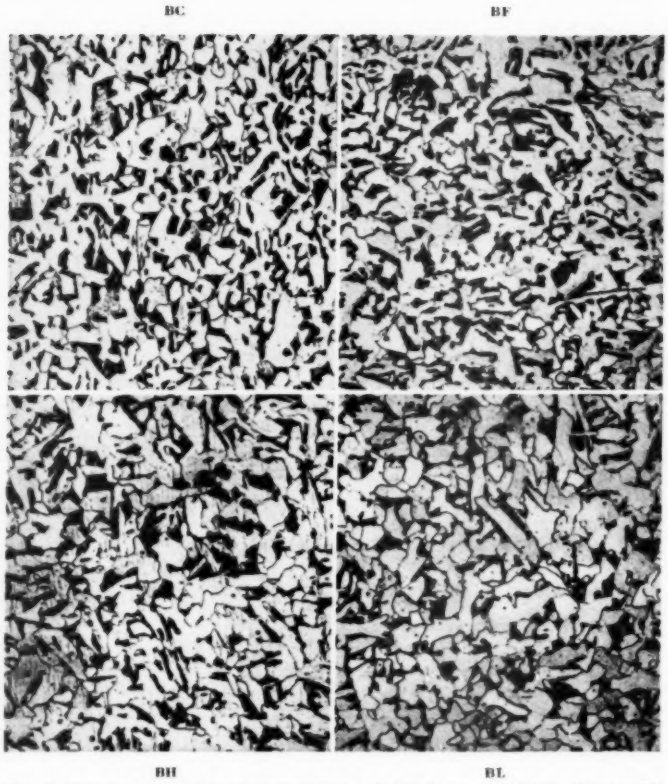


Fig. 1 Photomicrographs of steels tested. Original magnification, 100 ×; 2% nital etch

deflection bridge with the resulting unbalance from loading or deflecting detected, amplified and transmitted to a 3 FPI tube. A photographic record is made with a still camera. The load bridge and the deflection bridge contain an AB-7, SR-4 strain gage in each of the four arms. The strain gages are exposed to the room temperature.

EXPERIMENTAL TECHNIQUE

The specimens were tested in the special slow-bend testing machine under controlled deflection rates and temperatures. A specimen with a given geometry (triaxiality) was selected and tested at a constant temperature to fracture. The load-deflection curve was obtained. From this record the amount of *plastic deformation* preceding fracture was measured and recorded. Tests were then repeated on the same material with the same geometry, at the same deflection rate, but different constant temperatures and the resulting plastic deformations recorded. A temperature range of about 100° F. above the respective transition temperatures were thus studied.

To obtain a correlation between

Table 2—Results. Deflection and Angle of Bend for Various Specimens

Specimen No.	*Load, lb.*	*Deflection, in.*	*Angle*	*Specimen No.*	*Load, lb.*	*Deflection, in.*	*Angle*
BC 102—0.01 in. notch radius	0	0	0°0′	BH 103—0.01-in. notch radius	0	0	0°0′
	900	0.0015	0°2′		850	0.0029	0°4′
	1000	0.0052	0°7′		950	0.0086	0°12′
	1100	0.0168	0°24′		1050	0.0106	0°15′
	1200	0.0297	0°42′		1150	0.0179	0°25′
	1300	0.0444	1°3′		1250	0.0338	0°47′
	1400	0.0616	1°27′		1350	0.0852	1°59′
	1500	0.0861	2°1′		1450	0.1085	2°31′
	1600	0.1036	2°25		1550	0.1423	3°19′
	1700	0.1343	3°11′		1650	0.1788	4°10′
	1800	0.1625	3°49′				
BC 106—$^1/_{16}$-in. notch radius	0	0	0°0′	BC 103—0.01-in. notch radius	0	0	0°0′
	850	0.0034	0°5′		930	0.0056	0°8′
	950	0.0066	0°9′		1030	0.0092	0°13′
	1050	0.0178	0°25′		1130	0.0194	0°27′
	1150	0.0205	0°29		1230	0.0212	0°30′
	1250	0.0418	0°59′		1330	0.0467	1°5′
	1350	0.0655	1°32′		1430	0.0632	1°28
	1450	0.0884	2°4′		1530	0.0852	1°59′
	1550	0.1153	2°42′		1630	0.1074	2°30′
	1650	0.1446	3°24′		1730	0.1366	3°11
	1750	0.1793	4°13′		1830	0.1697	3°57′
BH 102—0.01-in. notch radius	0	0	0°0′	BC 107—$^1/_{16}$-in. notch radius	0	0	0°0′
	930	0.0109	0°15		900	0.0043	0°6′
	1030	0.0224	0°31′		1000	0.0129	0°18′
	1130	0.0363	0°51′		1100	0.0237	0°33′
	1230	0.0533	1°15′		1200	0.0394	0°55′
	1330	0.0742	1°45′		1300	0.0579	1°21′
	1430	0.1017	2°23′		1400	0.0785	1°50′
	1530	0.1316	3°5′		1500	0.1039	2°25′
	1630	0.1628	3°49′		1600	0.1324	3°5′
	1730	0.2018	4°44′		1700	0.1642	3°49′

Table 3—Results. Permanent Deformation vs. Testing Temperature

Average Deflection Rate = 0.0014 in./sec.

Specimen No.	Testing Temp. °F	permanent set inches	Specimen No.	Testing Temp. °F	permanent set inches
BC 16	-124	.0336	BF 11	-165	.0217
BC 22	-130	.0161	BF 23	-173	.0297
BC 6	-135	.0168	BF 3	-180	.0120
BC 2	-140	.0150	BF 4	-190	.0098
BC 3	-145	.0070	BF 2	-191	.0119
BC 7	-150	.0119	BF 6	-195	.0091
BC 9	-155	.0098	BF 7	-205	.0077
BC 10	-160	.0112	BF 15	-215	.0101
BC 11	-168	.0077	BF 8	-220	.0105
BC 15	-180	.0040	BF 16	-225	.0067
BC 12	-187	.0031	BF 17	-235	.0041
BC 23	-195	.0045	BF 9	-238	.0077
BC 14	-200	.0051	BF 14	-250	.0040
BC 13	-209	.0007	BF 24	-254	.0000
BC 18	-210	.0000	BF 25	-255	.0000
			BF 18	-260	.0000
			BF 13	-272	.0000

Specimen No.	Testing Temp. °F	permanent set inches	Specimen No.	Testing Temp. °F	permanent set inches
BH 9	-130	.0210	BL 2	-135	.0217
BH 7	-135	.0196	BL 21	-140	.0105
BH 2	-140	.0147	BL 24	-140	.0217
BH 3	-145	.0134	BL 20	-152	.0210
BH 6	-150	.0098	BL 5	-160	.0161
BH 8	-155	.0077	BL 6	-160	.0259
BH 10	-168	.0047	BL 7	-170	.0070
BH 11	-170	.0112	BL 8	-170	.0196
BH 17	-180	.0053	BL 19	-182	.0126
BH 12	-190	.0052	BL 12	-190	.0101
BH 14	-205	.0031	BL 14	-200	.0047
BH 13	-220	.0026	BL 16	-215	.0060
BH 18	-228	.0000	BL 25	-220	.0020
BH 15	-230	.0020	BL 13	-228	.0038
BH 22	-230	.0000	BL 18	-230	.0000
BH 21	-240	.0000	BL 17	-235	.0000

Specimen No.	Testing Temp. °F	permanent set inches	Specimen No.	Testing Temp. °F	permanent set inches
BC 63	-213	.0273	BF 63	-230	.0196
BC 67	-215	.0217	BF 55	-235	.0182
BC 54	-220	.0091	BF 64	-238	.0140
BC 57	-234	.0084	BF 69	-243	.0135
BC 68	-240	.0053	BF 58	-250	.0073
BC 58	-250	.0039	BF 59	-260	.0052
BC 59	-265	.0054	BF 70	-265	.0196
BC 60	-274	.0034	BF 60	-273	.0060
BC 61	-280	.0059	BF 61	-283	.0034
BC 64	-290	.0020	BF 62	-283	.0034
BC 65	-295	.0013	BF 65	-290	.0048
BC 66	-310	.0000	BF 67	-300	.0007
			BF 68	-305	.0014
			BF 66	-310	.0014
			BF 71	-320	.0019

Table 3 (*Contd.*)

Specimen No.	Testing Temp. °F	permanent set inches	Specimen No.	Testing Temp. °F	permanent set inches
BH 63	-209	.0137	BL 50	-205	.0245
BH 61	-215	.0119	BL 58	-215	.0147
BH 60	-220	.0112	BL 51	-225	.0175
BH 55	-225	.0098	BL 53	-230	.0133
BH 56	-240	.0034	BL 63	-233	.0105
BH 57	-255	.0054	BL 62	-240	.0034
BH 64	-260	.0054	BL 59	-250	.0027
BH 58	-272	.0020	BL 57	-255	.0035
BH 59	-275	.0020	BL 60	-265	.0020
BH 62	-280	.0000	BL 61	-270	.0034
BH 65	-282	.0033	BL 64	-275	.0014
BH 66	-295	.0000	BL 65	-275	.0014
BH 67	-295	.0000	BL 66	-278	.0074
			BL 69	-285	.0020
			BL 68	-295	.0020
			BL 70	-320	.0000

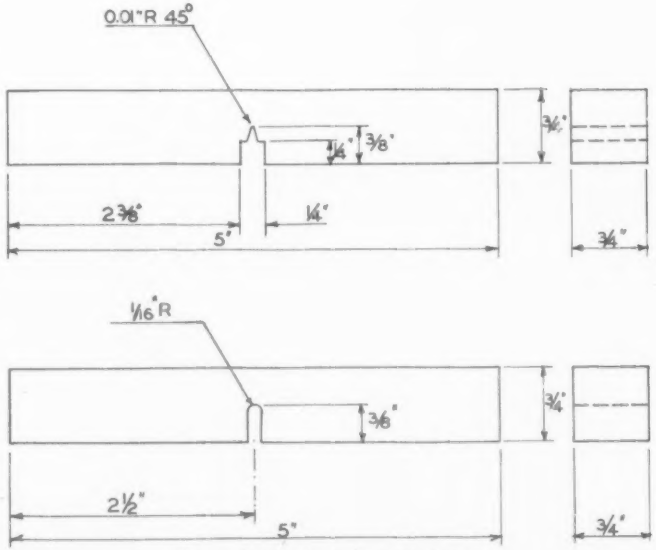


Fig. 2 Dimensions of test specimens

the amount of plastic deformation and the angle of bend, a setup shown in Fig. 3 was utilized. The specimens were loaded until a small permanent set was obtained. The "vertical" deflection was measured with a calibrated dial gage reading to the nearest 0.0005 in., mounted in a special fixture. The angle of bend was computed from the known dimension of the specimens. These loadings were repeated for several deflections on a number of specimens.

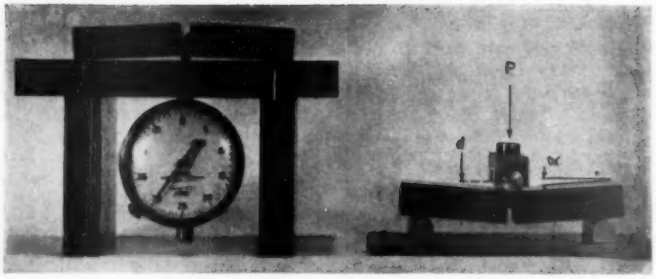


Figure 3

RESULTS

A. Permanent Deflection vs. Angle of Bend

Two different steels and two different notch geometries were tested. Table 2 lists the load in pounds required to produce a given permanent set, and the corresponding angular deformations computed from the known dimensions of the specimens. Figure 4 shows the plotted curve.

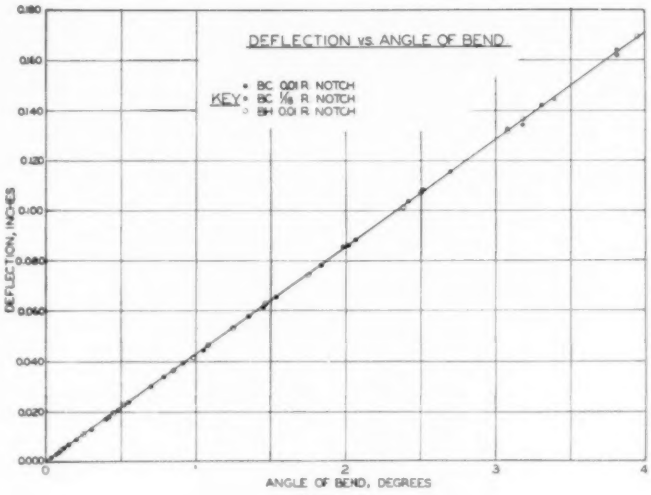


Figure 4

B. Permanent Deformation vs. Testing Temperature

Table 3 gives the summary of the slow-bend test results for four different steels, each tested, with two different notch geometries. Plots of Permanent Deformation vs. Testing Temperatures are shown in Figs. 5–8. Values taken from Fig. 4 are superimposed upon these graphs.

DISCUSSION

An inspection of the plotted curves (Figs. 5–8) will indicate a considerable amount of scatter. The relative magnitude and frequency of scatter seems to be independent of the notch geometry and the steels tested. This latter may be understood from the fact that the four steels were quite similar (see Table 1 and Fig. 1). Thus it may be concluded that the scatter is at least partially due to the steel itself. This statement is not

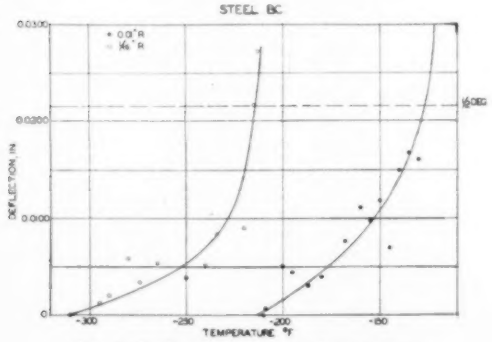


Fig. 5 Deflection vs. testing temperature

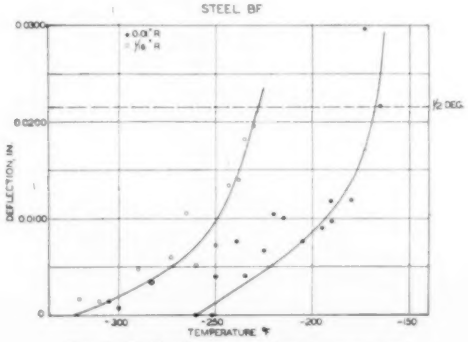


Fig. 6 Deflection vs. testing temperature

contrary to the findings of the extensive experiments on the impact properties of ferritic steels.[3] It was beyond the scope of the present study, but it would be of interest to determine the amount of scatter for a given steel, at constant geometry, deflection rate and temperature, using the amount of plastic flow as the measure of scatter.

The absolute value of the transition temperature (at a constant geometry and deflection rate) is a function of the material. It is not known, however, how the variation in geometry will affect the value of the transition temperature. In the present study two different notch geometries were investigated. Taking the bars with the 0.01-in. radius notch, the order of ductility seems to be BF, BH, BL, BC (the lower the transition temperature indicates more ductility). Looking at the values of the 1/16-in. radius bars the order appears as BF, BL, BC, BH. Again it is an interesting speculation as to how the deflection rate would influence the transition temperatures, keeping the other variables constant. Our present-day knowledge in this field has reached the frontiers and it has become imperative to conduct some systematic basic research in order to evaluate quantitatively the geometry and size effects on the brittle transition temperature.

The dotted lines marked 1/2° along the ordinates correspond to a permanent angular deflection of 1/2° preceding fracture. This value, equal to 0.0215 in. of permanent deflection was obtained from Fig. 4. It should be noted that for the small angular deflections measured the relationship between angle of bend and deflection is independent of the notch radius and the type of steel. This is a purely formal relationship and no deep significance should be attached to it. It is noteworthy at this point to observe that to produce a given angular bend, however, requires different amounts of load (stress) for the different steels and geometries (see Table 2).

At an angle of bend of 1/2° preceding fracture the testing temperatures (*not* the transition temperatures) were obtained from Figs. 5–8. Table 4 lists these values.

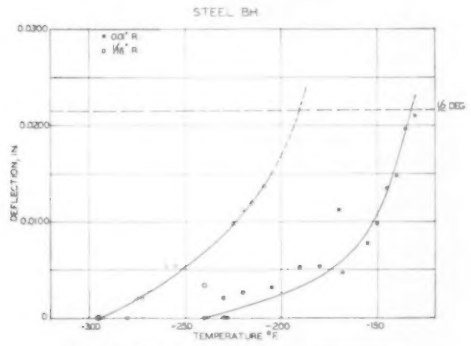


Fig. 7 Deflection vs. testing temperature

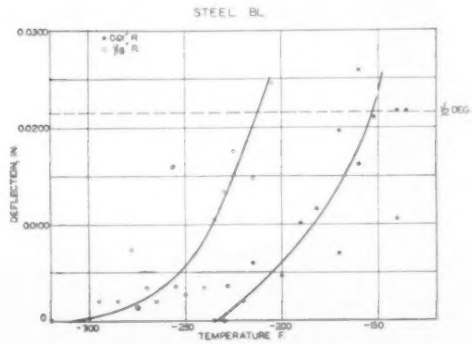


Fig. 8 Deflection vs. testing temperature

Table 4—Testing Temperatures for Several Steels at 1/2° Angle of Bend Preceding Fracture

	Testing temperature, ° F.	
Steel designation	*1/16-in. notch radius*	*0.01-in. notch radius*
BC	−214	−127
BF	−228	−168
BH	−190	−132
BL	−212	−148

It is noted that an angle of bend of 1/2° preceding fracture corresponds to temperatures from 85 to 108° F. *above* the brittle transition temperatures as used in the M.I.T. test. Based on the limited and rather specific observations of the present investigation, it may be stated that tests conducted in order to obtain brittle transition temperature values should limit the amount of macroscopic plastic flows to an angle of bend of about 2 min. or less.

CONCLUSIONS

Four hot-rolled, low-carbon steel plates were selected to study the relationship between angle of bend and permanent deflection preceding the fracture of notched-bar specimens. The tests were conducted isothermally at a constant deflection rate. The results indicated that (*a*) the absolute value of the transition temperatures are functions of the geometries as well as of the materials; (*b*) at a permanent angular bend of 1/2° the testing temperature at fracture for the notch geometries investigated was about 100° F. above the respective brittle transition temperatures as used in the M.I.T. test.

ACKNOWLEDGMENT

The authors wish to express their appreciation to David Swan who suggested this topic for investigation. William Spraragen was most resourceful in procuring the necessary funds for carrying out this study.

Bibliography

1. MacGregor, C. W., Grossman, N., and Shepler, P. R., "Correlated Brittle Fracture Studies of Notched Bars and Simple Structures," THE WELDING JOURNAL, Research Suppl., XII (1), 50-s to 56-s (1947).
2. Grossman, N., and Shepler, P. R., "The Effect of Welding Technique on Brittle Transition Temperature," *Ibid.*, Research Suppl., XII (6), 321-s to 331-s (1947).
3. Gillett, H. W., and McGuire, F. T., "Behavior of Ferritic Steels at Low Temperatures: Part II," A.S.T.M., (December 1945).

Cooling Rates in Arc Welds in ½-In. Plate

Experimental data and mathematical investigations of temperature, temperature gradient, and cooling rate at points adjacent to an arc weld in ½" steel plate

by Ernest F. Nippes, Lynn L. Merrill and Warren F. Savage

SUMMARY

As A result of quantitative temperature measurements in the neighborhood of arc welds made in ½-in. steel plate, a series of differential equations was developed. These equations express the temperature distribution adjacent to an arc weld as a function of time, distance from weld center line and welding variables. Graphical solutions have been included which permit calculation of the heating and cooling cycles experienced by any point in the vicinity of an arc weld in ½-in. steel plate. These solutions provide the basis of subsequent reports involving the design and application of a time-temperature control device for exact duplication of weld heat-affected structures.

Ernest F. Nippes and **Warren F. Savage** are associated with the Welding Laboratory, Dept. of Metallurgy, Rensselaer Polytechnic Institute, Troy, N. Y., and **Lynn L. Merrill** is associated with the Clarkson College of Technology, Potsdam, N. Y., formerly with the Dept. of Mathematics at Rensselaer Polytechnic Institute.

* Hess, W. F., Merrill, L. L., Nippes, E. F., Jr., and Bunk, A. P., "The Measurement of Cooling Rates Associated with Arc Welding and Their Application to the Selection of Optimum Welding Conditions," **22** (9), Research Suppl., 377-s to 422-s (1943).

MATHEMATICAL ANALYSIS

It was shown in a former investigation* that the temperature at any point at a distance d from the center line of an arc weld may be determined from the equation

$$T - T_o = \frac{Q(I.F.)}{4.185(2\pi K)g^{(1-\beta)}(v^2s^2+d^2)^{(1+\beta/4)}} \times \left(\frac{\pi}{2\lambda v}\right)^{(1-\beta/2)} \cdot e^{-\lambda v(\sqrt{v^2s^2+d^2}-vs)} \quad (1)$$

where

T	=	plate temperature, ° C.
T_o	=	initial plate temperature, ° C.
Q	=	actual watts in the arc.
$I.F.$	=	input factor.*
β	=	beta factor.*
K	=	thermal conductivity, cal./sec. cm., ° C.
2λ	=	thermal diffusivity = $K\delta c$, cm.²/sec.
δ	=	density, gm./cm.³
c	=	specific heat, cal./gm., ° C.
v	=	speed of electrode, cm./sec.
s	=	time in seconds after the electrode passes the point.
g	=	plate thickness, cm.
d	=	distance to point from center line of weld, cm.

It was found also that the cooling rate at a point

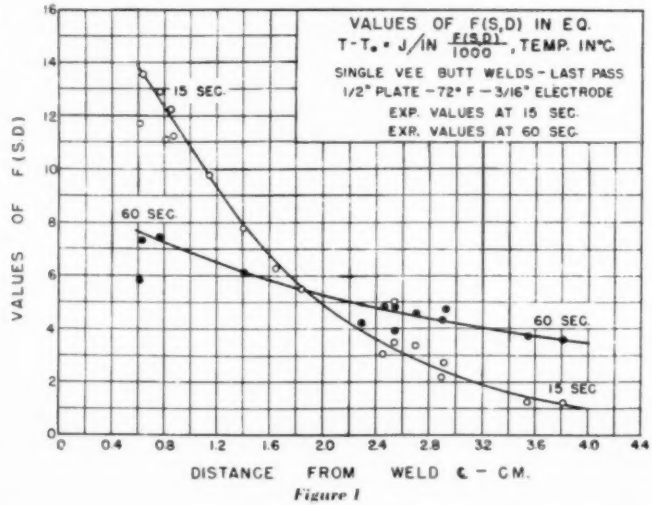


Figure 1

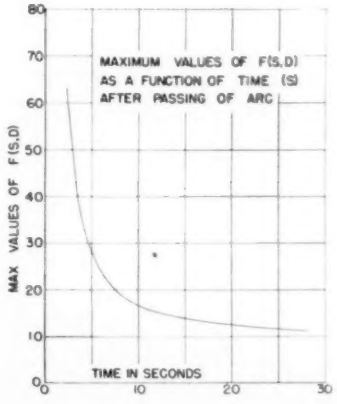


Figure 2

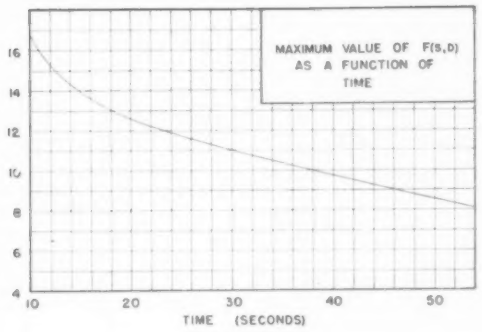


Figure 3

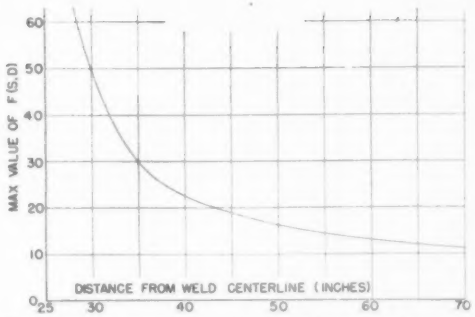


Fig. 4 Maximum values of $F(s, d)$ as a function of distance from weld center line

Table 1—Experimental Values of $F(s, d)$ Obtained from the Equation $F(s, d) = \frac{(T - T_0)\ (1000)}{\text{Joules/Inch}}$

Temperature in ° C. Single-Vee Butt Welds, Last Pass. One-Half-Inch Plates Initially at Room Temperature, 1/16-In. Electrodes. Distances from Center of Weld

Time in Sec.	Chart No. 6 NE 8620 TC 1	Chart No. 6 NE 8620 TC 2	Chart No. 7 NE 8620 TC 1	Chart No. 7 NE 8620 TC 2	Chart No. 8 NE 8620 TC 1	Chart No. 8 NE 8620 TC 2	Chart No. 9 Ship Steel	Chart No. 10 Ship Steel	Chart No. 11 Ship Steel Tc 1	Chart No. 11 Ship Steel TC 2	Chart No. 12 Ship Steel	Chart No. 13 NE 8620	Chart No. 14 NE 8620 TC 1
	1.14 cm.	1.4 cm.	1.85 cm.	2.46 cm.	1.65 cm.	2.79 cm.	0.61 cm.	2.54 cm.	0.84 cm.	2.7 cm.	2.92 cm.	2.9 cm.	0.86 cm.
0	1.93	0.590	0.90	0.128	1.54*		4.56			0	0	0	1.74
2	4.09	1.23	1.59	0.321	2.87*		20.5		13.1	0	0	0	7.94
5	9.17	3.47	2.94	0.738	4.56		19.3	4.47	16.1	0.666	0.333	0.246	12.9
7.5	10.55	5.47	3.85	1.35	5.25		17.1	4.80	14.8	1.46	0.90	0.660	12.6
10	10.50	6.85	4.56	1.89	5.32		14.5	4.90	13.6	2.24	1.60	1.11	12.1
15	9.74	7.76	5.47	3.05	6.22		11.7	4.80	12.2	3.36	2.74	2.17	11.2
20	9.06	7.76	5.90	3.82	6.27		10.6	4.72	10.85	4.06	3.87	2.85	10.3
30	8.11	7.27	6.12	4.59	6.12	4.76	8.3	4.68		4.72	4.50	3.81	
40	7.52	6.96	6.02	4.86		4.70	7.1	4.47		4.87	4.90	4.03	
60		6.10		4.86		4.21	5.83	3.92		4.60	4.73	4.34	
80		5.30		4.59		3.84	5.05	3.60		4.24	4.27	4.03	
100		4.68		4.17		3.60	4.43			3.79	4.10	3.84	
120		4.06		3.67		3.24				3.64	3.94	3.78	
150										3.15	3.33	3.50	
180										2.92	3.24	3.22	

Time in Sec.	Chart No. 14 NE 8620 TC 2	Chart No. 15 NE 8620	Chart No. 16 NE 8620 TC 1	Chart No. 16 NE 8620 TC 2	Chart No. 17 NE 8620	Chart No. 18 NE 8620
	2.54 cm.	0.635 cm.	0.813 cm.	3.82 cm.	0.76 cm.	3.95 cm.
0	0	3.40	0.658	0	3.03	0
2	0.249	off scale	5.93	0	18.6	0
5	0.84	26.7	12.4	0.195	24.8	0.241
7.5	1.89	21.1	12.65	0.537	18.5	0.462
10	2.33	17.1	12.1	0.658	15.7	0.650
15	3.45	13.52	11.1	1.24	12.9	1.73
20	4.1	12.2	10.45	1.83	11.75	1.86
30	4.95	9.9		2.46	10.3	3.04
40	5.17	8.45		3.17	8.98	3.47
60	4.85	7.32		3.63	7.46	3.76
80	4.57	5.80		3.76	6.46	3.86
100	4.42	5.05		3.71	5.63	3.71
120	3.98	4.58		3.61	5.30	3.54
150	3.63	4.10		3.51	4.73	3.42
180	3.30	3.64		3.22	4.27	3.08

* Curve very irregular.

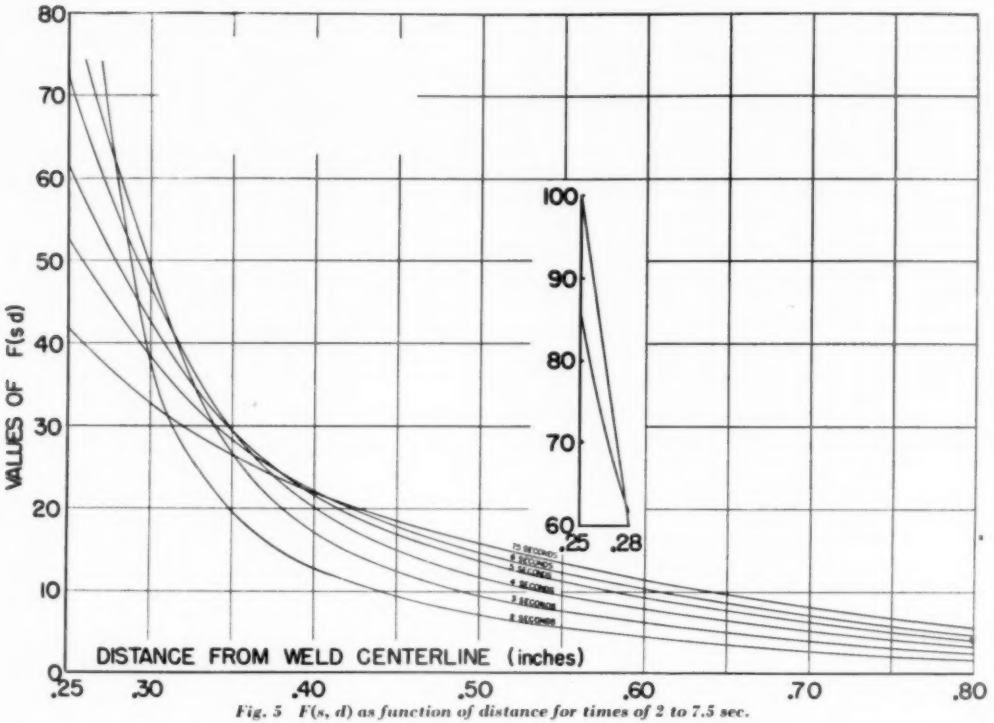


Fig. 5 F(s, d) as function of distance for times of 2 to 7.5 sec.

at the edge of a weld is directly proportional to $(T-T_0)$ and dependent on the energy input per unit length but independent of the travel speed, in the range from 5 to 11 in. per minute. It follows that the values of $(T-T_0)$ likewise must be dependent on the energy input but independent of the travel speed in the same range. This means that Equation 1 may be written

$$T - T_0 = (\text{joules/inch})\, f(s, d) \qquad (2)$$

Actually $f(s, d)$ depends on the values of the beta and input factors, but since these in turn depend on s, d and v, f may be considered as a function of s and d only.

Equation 2 may be verified for small values of d, $d \angle\angle vs$, by substituting in Equation 1

$$Q = (\text{joules/inch})\, \frac{v}{2.54} \qquad (3)$$

$$e^{-\lambda s(\sqrt{v^2s^2+d^2}-vs)} \doteq e^{\frac{-\lambda d^2}{2s}} \qquad (4)$$

and

$$(v^2s^2 + d^2)^{\left(\frac{1+\beta}{4}\right)} \doteq (vs)^{\left(\frac{1+\beta}{2}\right)} \qquad (5)$$

The resulting expression is independent of v as may be seen by inspection. The extension to larger values of d is based on the above reasoning.

To provide factors of convenient magnitude let

$$f(s, d) = \frac{F(s, d)}{1000} \qquad (6)$$

then Equation 2 becomes

$$T - T_0 = (\text{joules/inch})\, \frac{F(s, d)}{1000} \qquad (7)$$

Table 2—Values of $F(s, d)$ in Equation $(T - T_0) = \text{Joules/Inch}\ \frac{F(s, d)}{1000}$

Temperature in ° F. Single-Vee Butt Welds, Last Pass. One-Half-Inch Plates Initially at Room Temperature, 3/16-In. Electrodes. Distance in Inches

Time Sec.	d=	.25	.30	.40	.50	.60	.70	.80	1.00	1.20	1.40	1.60
2	100	36.8	12.90	7.17	4.50	2.70	1.70	.20	0	0	0	
5	61.6	42.44	21.64	13.68	9.36	6.30	4.05	1.65	.18	0	0	
7.5	41.8	32.72	22.32	15.90	11.42	8.02	5.67	2.82	1.08	0.36	0	
10	31.5	27.6	21.24	16.2	12.3	9.05	6.90	3.96	2.16	1.10	0.54	
15	24.5	22.85	19.5	15.93	13.00	10.35	8.46	5.81	3.91	2.56	1.71	
20	21.8	20.6	18.05	15.4	13.1	11.1	9.40	6.93	5.18	3.85	2.88	
30	18.6	17.8	16.05	14.23	12.65	11.3	10.15	8.06	6.60	5.50	4.50	
40	16.4	15.8	14.55	13.17	11.95	10.9	10.02	8.52	7.28	6.21	5.35	
60	13.65	13.25	12.35	11.4	10.6	9.85	9.39	8.40	7.56	6.85	6.12	
80	11.90	11.55	10.76	10.01	9.36	8.80	8.40	7.72	7.15	6.72	6.33	
100	10.65	10.35	9.75	9.14	8.60	8.13	7.75	7.15	6.72	6.40	6.12	
120	9.71	9.44	8.94	8.38	7.92	7.53	7.17	6.66	6.40	6.16	5.96	
150	8.74	8.50	8.06	7.58	7.17	6.85	6.63	6.27	6.07	5.89	5.77	
180	7.86	7.69	7.35	7.0	6.60	6.45	6.25	5.97	5.85	5.73	5.67	

The expressions for space rate of change of temperature, or temperature gradient, and time rate of change of temperature, or cooling rate, become respectively

$$G = (\text{joules/inch})\, \frac{F_d\,(s, d)}{1000} \qquad (8)$$

and

$$\text{C. R.} = (\text{joules/inch})\,\frac{F_s(s, d)}{1000} \qquad (9)$$

where F_d (s, d) is the negative of the slope of the $F(s, d)$ vs. distance curve for constant time, and $F_s(s, d)$ is the negative of the slope of the $F(s, d)$ vs. time curve for constant distance.

When a set of values of F has been determined experimentally for various values of time and distance, the values of F_d and F_s may be obtained by finding the slopes of the curves as indicated above. The values of F, F_d and F_s may then be used to determine temperature (Equation 7), space temperature gradient (Equation 8) and cooling rate (Equation 9) at any value of time and distance and for any given value of energy input in joules per inch.

EXPERIMENTAL VERIFICATION

To determine the values of F for $^1/_2$-in. plates, several single-vee butt welds were made with the plates initially at room temperature, using $^3/_{16}$-in. E-6020 electrodes on NE8620 and Ship Steel plates. Thermocouples were placed at various distances from the center line. Records of temperature vs. time were made using the equipment previously described.* Equation 7 was then used to calculate the values of F, for values of time ranging from 2 sec. after the passing of the electrode and for

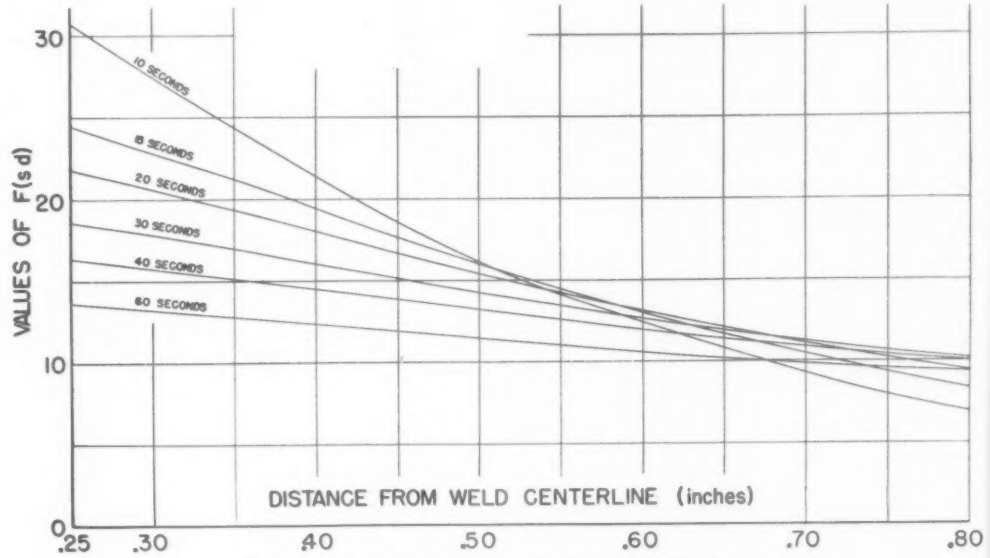


Fig. 6 F(s, d) as function of distance for times of 10 to 60 sec.

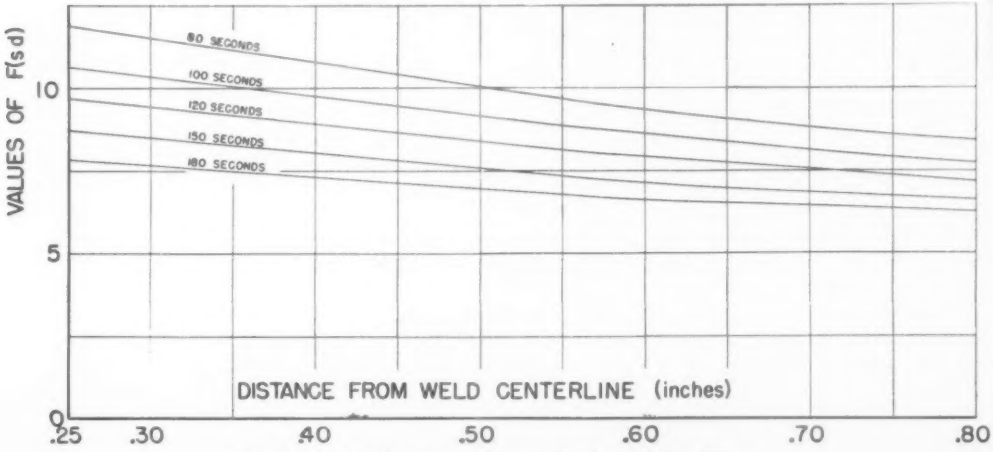


Fig. 7 F(s, d) as function of distance for times of 80 to 180 sec.

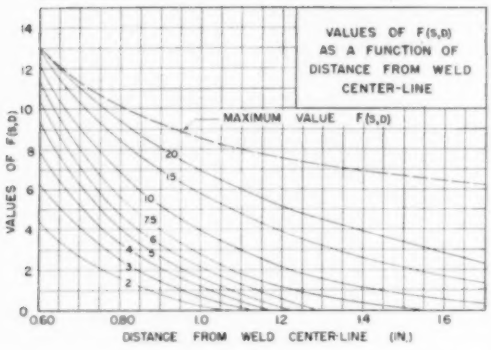

VALUES OF F(s,0) AS A FUNCTION OF DISTANCE FROM WELD CENTER-LINE
MAXIMUM VALUE F(s,0)
VALUES OF F(s,0)
DISTANCE FROM WELD CENTER-LINE (IN.)

Figure 8

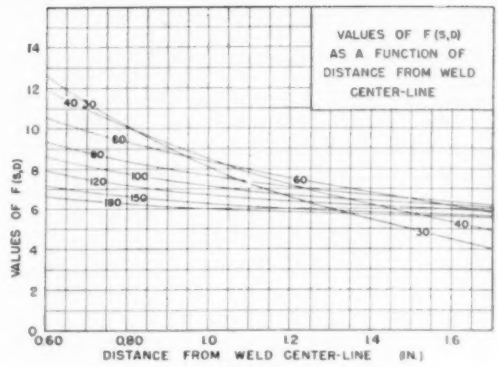


Figure 9

Table 2A—Values of $F(s, d)$ in Equation $(T - T_0)$ = Joules/Inch $\frac{F(s,d)}{1000}$

Temperature in ° F. Single-Vee Butt Welds, Last Pass. One-Half-Inch Plates Initially at 72° F., 3/16-In. Electrodes. Distance in Inches

Time Sec. d=	.25	.26	.27	.28	.29	.30	.31	.32	.33	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44
2	100.0	87.0	74.0	60.0	47.0	36.8	31.10	27.80	24.50	21.90	19.65	17.85	16.25	15.00	13.90	12.90	12.10	11.30	10.65	10.0
3	85.60	74.30	67.80	61.20	54.80	49.20	43.00	37.80	33.20	29.36	26.48	23.98	21.80	19.90	18.30	16.85	15.76	14.84	13.96	13.20
4	72.50	66.20	60.60	55.40	50.80	46.40	42.45	38.46	35.35	32.10	29.30	26.96	24.92	23.08	21.48	20.00	18.72	17.60	16.60	15.80
5	61.60	57.16	53.04	49.16	45.70	42.44	39.40	36.50	34.00	31.80	29.30	27.50	25.84	24.30	22.88	21.64	20.48	19.44	18.52	17.70
6	52.70	49.52	46.36	43.52	40.80	38.40	36.00	33.76	31.72	29.92	28.32	26.88	25.64	24.44	23.32	22.32	21.32	20.36	19.52	18.72
7.5	41.90	39.52	37.56	35.80	34.20	32.72	31.30	30.0	28.72	27.50	26.50	25.50	24.62	23.76	22.98	22.18	21.45	20.70	20.06	19.40
10	31.50	30.70	29.90	29.15	28.40	27.60	26.92	26.24	25.60	24.92	24.32	23.66	23.04	22.42	21.90	21.24	20.68	20.16	19.62	19.11
15	24.50	24.18	23.84	23.50	23.19	22.85	22.53	22.22	21.90	21.57	21.23	20.90	20.56	20.20	19.84	19.50	19.10	18.75	18.40	18.05
20	21.8	21.56	21.32	21.08	20.83	20.60	20.33	20.09	19.83	19.59	19.33	19.09	18.83	18.58	18.32	18.05	17.78	17.50	17.20	16.95
30	18.6	18.45	18.30	18.13	17.97	17.80	17.65	17.42	17.30	17.13	16.94	16.76	16.59	16.41	16.23	16.05	15.86	15.67	15.49	15.31
40	16.40	16.28	16.16	16.03	15.91	15.80	15.69	15.58	15.48	15.33	15.21	15.10	14.96	14.81	14.68	14.55	14.40	14.25	14.12	13.97
60	13.65	13.57	13.50	13.44	13.33	13.25	13.17	13.09	13.00	12.92	12.83	12.74	12.65	12.55	12.45	12.35	12.25	12.15	12.05	11.95
80	11.90	11.84	11.78	11.69	11.61	11.55	11.46	11.39	11.31	11.29	11.16	11.09	11.01	10.94	10.86	10.78	10.68	10.61	10.53	10.46
100	10.65	10.60	10.54	10.47	10.41	10.35	10.30	10.23	10.17	10.11	10.05	9.99	9.93	9.87	9.81	9.75	9.70	9.63	9.57	9.51
120	9.71	9.66	9.61	9.56	9.51	9.44	9.40	9.35	9.30	9.25	9.20	9.15	9.10	9.05	9.00	8.94	8.87	8.81	8.75	8.70
150	8.74	8.69	8.64	8.60	8.55	8.50	8.46	8.41	8.36	8.32	8.27	8.23	8.19	8.15	8.10	8.05	8.00	7.95	7.91	7.85
180	7.86	7.83	7.79	7.75	7.71	7.69	7.65	7.61	7.58	7.55	7.52	7.48	7.45	7.41	7.38	7.35	7.31	7.27	7.24	7.20

Time Sec.	.45	.46	.47	.48	.49	.50	.51	.52	.53	.54	.55	.60	.70	.80	1.00	1.20	1.40	1.60
2	9.45	8.90	8.45	7.93	7.55	7.17	6.85	6.50	6.20	5.95	5.65	4.5	2.70	1.70	0.20	0	0	0
3	12.55	11.90	11.30	10.70	10.15	9.60	9.10	8.65	8.25	7.90	7.60	6.30	4.05	2.50	0.70	0	0	0
4	15.10	14.35	13.58	13.00	12.45	11.85	11.30	10.75	10.30	9.90	9.50	7.90	5.25	3.30	1.18	0	0	0
5	15.92	16.16	15.48	14.88	14.24	13.68	13.08	12.56	12.08	11.64	11.10	9.36	6.30	4.05	1.65	0.18	0	0
6	17.92	17.20	16.52	15.84	15.28	14.72	14.16	13.64	13.20	12.76	12.26	10.44	7.15	4.76	2.13	0.60	0	0
7.5	18.74	18.19	17.59	17.00	16.43	15.90	15.33	14.84	14.36	13.88	13.40	11.42	8.02	5.67	2.82	1.20	0.36	0
10	18.89	18.07	17.36	17.10	16.62	16.20	15.75	15.30	14.90	14.45	14.10	12.30	9.05	6.90	3.96	2.16	1.10	0.54
15	17.70	17.30	16.95	16.60	16.25	15.93	15.60	15.30	15.00	14.69	14.39	13.00	10.35	8.46	5.81	3.91	2.56	1.71
20	15.70	16.45	14.18	15.90	15.65	15.40	15.18	14.95	14.65	14.42	14.20	13.10	11.10	9.40	6.93	5.18	3.85	2.88
30	15.12	14.94	14.76	14.59	14.41	14.23	14.06	13.88	13.72	13.56	13.40	12.65	11.20	10.15	8.06	6.60	5.50	4.50
40	13.84	13.70	13.57	13.44	13.30	13.17	13.05	12.92	12.80	12.67	12.55	11.98	10.90	10.02	8.52	7.26	6.21	5.35
60	11.86	11.76	11.66	11.57	11.48	11.40	11.31	11.22	11.13	11.04	10.96	10.60	9.85	9.39	8.40	7.56	6.88	6.12
80	10.37	10.30	10.22	10.15	10.07	10.01	9.94	9.87	9.80	9.74	9.67	9.36	8.80	8.40	7.72	7.15	6.72	6.33
100	9.45	9.30	9.33	9.26	9.20	9.14	9.08	9.03	8.97	8.92	8.87	8.60	8.13	7.75	7.15	6.72	6.40	6.12
120	8.68	8.60	8.54	8.49	8.44	8.38	8.33	8.27	8.23	8.18	8.14	7.92	7.52	7.17	6.66	6.40	6.16	5.96
150	7.82	7.77	7.72	7.67	7.63	7.58	7.53	7.49	7.44	7.40	7.35	7.17	6.85	6.63	6.27	6.07	5.89	5.77
180	7.17	7.14	7.11	7.07	7.04	7.00	6.96	6.92	6.88	6.79	6.80	6.60	6.45	6.25	5.97	5.85	5.73	5.67

values of distance ranging from 0.25 to 1.6 in. from the center line of the weld.

Since the exact location of the center line of the weld could not be determined until completion of the weld, the thermocouples were placed in approximately the desired positions and their exact distances measured after welding. The calculated values of F were then plotted against distance and joined by a smooth curve. Intermediate values of F were found from this curve. To illustrate the method, two such curves are shown in Fig. 1 for values of time of 15 and 60 sec., respectively. The plotted points are the experimentally determined values of F.

Table 1 shows experimental values of F for values of time up to 180 sec. In Table 1 and Fig. 1 distances are in centimeters and the values of F are those which are required in Equation 7 to give $(T-T_0)$ in degrees Centigrade.

Table 2 shows a complete set of values of F obtained from curves of the type shown in Fig. 1 but giving $(T-T_0)$ in degrees Fahrenheit for various distances in inches and for values of time up to 180 sec.

Table 2A shows the values of F extended to include data at 3, 4 and 6 sec. and at 0.01-in. intervals from 0.25 to 0.55 in. They were obtained by first plotting the values of F vs. distance for the times 2, 5, 7.5, 10 and 15 sec. and then using these curves to find curves of F vs. time for the distances 0.25 to 0.55 in. at 0.01 in. intervals. The extension to this range was complicated by the fact that the measured curves of temperature vs. time rose very sharply for thermocouples placed near the weld and in many cases did not show the maximum value at all. It was not possible to obtain reliable data for any values of time between 2 and 5 sec. where most of the maximum values of F occurred.

By drawing the known portions of the curves, however, it was apparent that the curves for 0.27 and 0.28 in. had maximum values at about 2 sec. where values of F were known. The curve for 0.36 in. had a maximum value near 5 sec. where

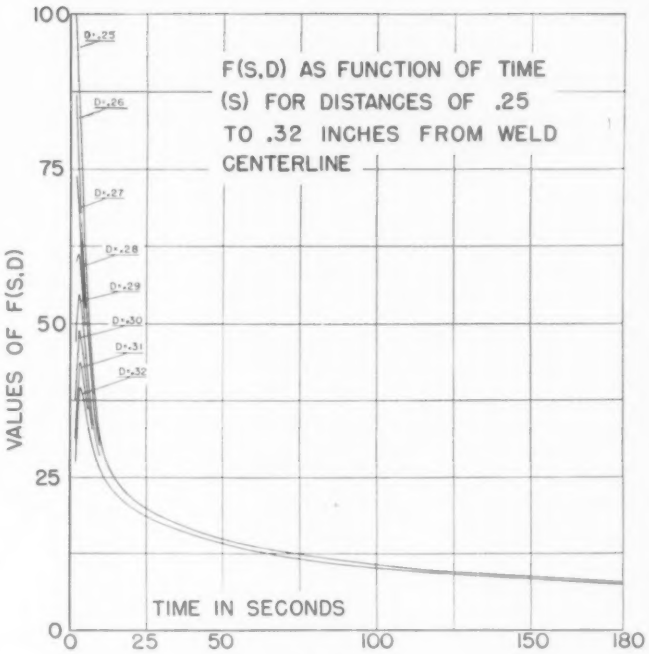


Figure 10

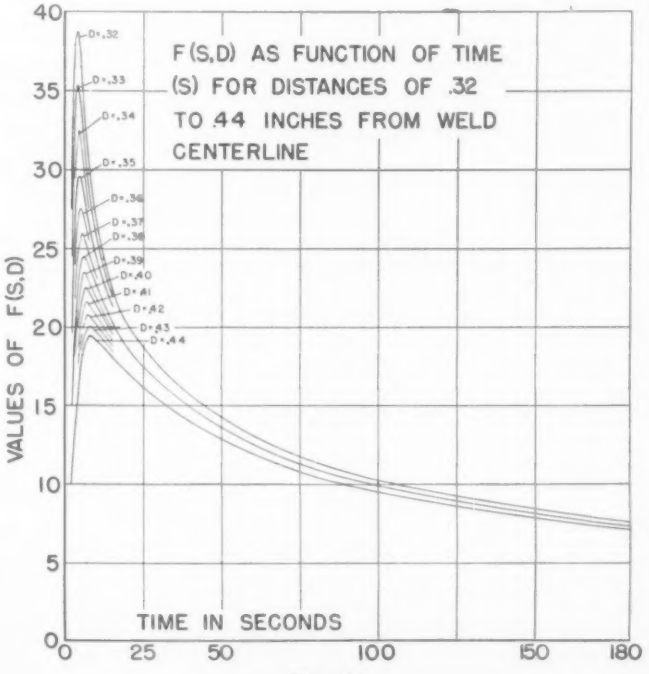


Figure 11

Table 3—Values of $F_d(s, d)$ in Equation G = Joules/Inch $\frac{F_d(s, d)}{1000}$

Single-Vee Butt Welds, Last Pass. One-Half-Inch Plates Initially at Room Temperature, 5/16-In. Electrodes. Gradient in ° F./Inch. Distance in Inches

Time Sec.	d= 0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.70	0.80	1.00	1.20	1.40	1.60
2	1350*	800*	250	95.0	57.0	37.0	28.0	22.0	14.0	8.80	2.50	0	0	0
3	910*	600*	235	119.5	66.5	45.0	34.5	27.3	19.0	13.3	5.80	1.20	0	0
4	625*	440*	214	128	75.5	51.8	40.3	32.1	22.8	16.6	8.20	2.70	0	0
5	450	315	187	119	79.3	57.4	44.5	35.5	25.2	18.7	10.0	3.80	0	0
6	328	228	152	102.5	74.0	58.0	46.0	37.5	26.7	19.6	11.0	4.50	0	0
7.5	200	145	105	82.0	65.5	53.7	44.7	37.7	27.3	20.2	11.7	6.50	2.50	0
10	78.0	72.5	66.0	59.5	52.6	45.8	39.6	34.5	25.7	19.7	12.4	7.70	4.60	2.50
15	30.0	33.2	35.5	36.3	35.4	33.5	30.5	27.0	21.2	17.0	11.2	8.80	5.50	4.00
20	23.0	24.8	26.0	26.5	26.0	24.7	23.1	21.3	17.4	14.2	10.0	7.70	6.00	4.60
30	15.3	16.6	17.4	17.8	17.6	16.9	16.0	15.0	12.95	11.0	8.20	6.60	5.50	4.70
40	11.4	12.42	13.0	13.2	12.95	12.55	12.0	11.3	9.82	8.50	6.60	5.55	4.90	4.50
60	8.00	8.70	9.20	9.45	9.28	8.80	8.20	7.60	6.52	5.70	4.65	4.05	3.72	3.50
80	6.40	7.00	7.40	7.52	7.40	7.05	6.58	6.10	5.10	4.40	3.65	3.12	2.86	2.68
100	5.55	5.98	6.30	6.40	6.18	5.80	5.48	4.95	4.20	3.60	2.86	2.42	2.17	1.97
120	4.85	5.22	5.48	5.55	5.33	5.00	4.63	4.28	3.58	3.00	2.27	1.82	1.60	1.42
150	4.10	4.40	4.55	4.55	4.40	4.12	3.88	3.48	2.82	2.30	1.55	1.15	0.90	0.75
180	3.40	3.65	3.81	3.82	3.68	3.43	3.22	2.82	2.20	1.70	1.00	0.62	0.38	0.20

* These values were obtained by extrapolation and should be considered as less exact than the others.

the value of F was known. These three maximum points were estimated and plotted. The maximum values of F for all distances greater than 0.36 in. were determined with considerable accuracy from the curves of F vs. time for such distances. A curve, the "maximum F vs. time" curve, was then drawn through these points and extended as a trial curve through the three estimated points. Similarly a trial "maximum F vs. distance" curve was drawn and from it the maximum values of F for all the above distances were obtained. Maximum points for all such distances were then located on the maximum F vs. time curve and curves drawn through these points and the known values of F at 2 and 5 sec.

The first trial curves showed irregularities and the process was repeated until a family of smooth regular curves was obtained. The final values of maximum F (s, d) vs. time are shown in Figs. 2 and 3, and the maximum F (s, d) vs. distance is shown in Fig. 4.

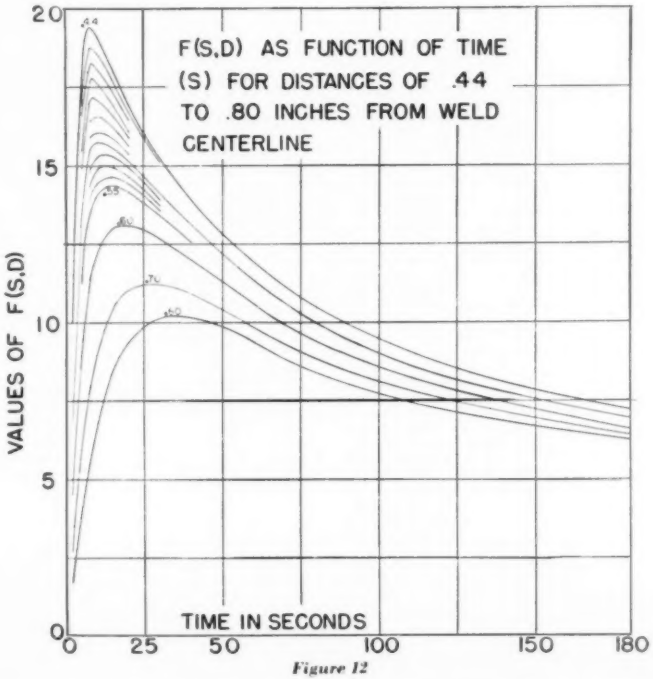


Figure 12

Figures 5, 6 and 7 show values of $F(s, d)$ required in Equation 7, where $(T-T_0)$ is in degrees Fahrenheit, plotted as a function of distance in inches for various times. While Figs. 5, 6 and 7 show the values for dis-

Table 4—Values of $F_s(s, d)$ in Equation C. R.° = Joules/Inch $\frac{F_s(s, d)}{1000}$

Single-Vee Butt Welds, Last Pass. One-Half-Inch Plates Initially at Room Temperature, 3/16-In. Electrodes. Cooling Rate or Heating Rate in ° F. per Second. Distance in Inches

Time Sec.	d= 0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.70	0.80	1.00	1.20	1.40	1.60
4	11.4	3.60	0.80	2.15	2.45	2.10	1.78	1.52	1.13	0.80	0.45	0.20	--	--
5	9.60	5.00	0.90	1.10	1.50	1.50	1.40	1.20	0.95	0.73	0.47	0.28	--	--
6	7.95	4.30	1.30	0.25	0.85	1.00	0.98	0.88	0.75	0.66	0.47	0.32	--	--
7.5	5.80	3.15	1.30	0.29	0.20	0.40	0.50	0.53	0.55	0.53	0.45	0.35	0.25	0.15
10	3.05	1.40	0.65	0.39	0.20	0.00	0.12	0.23	0.36	0.40	0.395	0.37	0.35	0.32
15	0.80	0.61	0.435	0.31	0.18	0.082	0.02	0.08	0.19	0.25	0.29	0.29	0.27	0.24
20	0.45	0.38	0.30	0.24	0.165	0.100	0.04	0.02	0.09	0.14	0.19	0.196	0.20	0.196
30	0.28	0.242	0.20	0.174	0.138	0.110	0.078	0.058	0.01	0.024	0.07	0.092	0.11	0.120
40	0.190	0.172	0.155	0.140	0.120	0.110	0.090	0.078	0.059	0.02	0.020	0.042	0.058	0.070
60	0.105	0.100	0.044	0.088	0.082	0.075	0.070	0.065	0.054	0.044	0.025	0.005	0.010	0.020
80	0.070	0.066	0.063	0.059	0.057	0.054	0.051	0.048	0.042	0.037	0.028	0.020	0.012	0.004
100	0.050	0.048	0.046	0.044	0.043	0.041	0.039	0.037	0.034	0.031	0.025	0.020	0.015	0.010
120	0.044	0.042	0.040	0.038	0.037	0.035	0.034	0.032	0.029	0.027	0.021	0.017	0.012	0.008

° Values of $F_s(s, d)$ above the heavy lines give heating rates, values below the heavy lines give cooling rates.

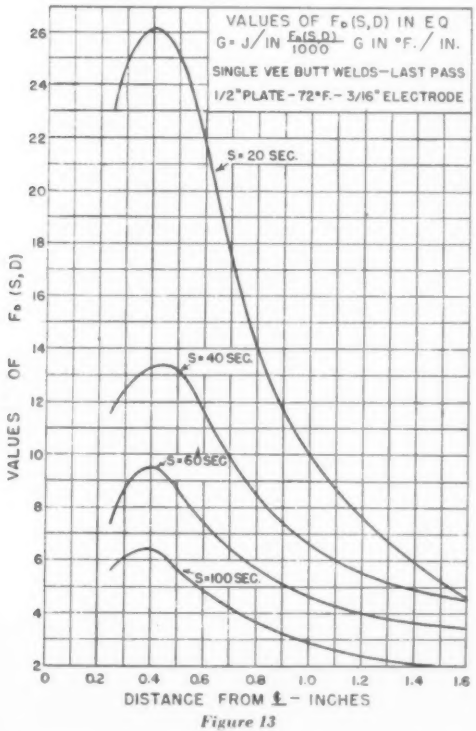


Figure 13

Table 5—Multipliers to Convert Tabular Values of F, F_d and F_s (Tables 2, 2A, 3 and 4) to Corresponding Values at Preheat Temperatures Up to 400° F.

Plate temperature, T_0, ° F.	*Multiplier*
32	1.02
72	1.00
210	0.95
400	0.87

Table 6—Comparison of Measured and Calculated Values of Temperature with Plate Preheated to 400° F., 3/16-In. Electrode

Chart No. 19 T_0 = 400°F., 37,600 Joules/Inch

	TC 1 d = 1.04"			TC 2 d = 1.23"		
Time Sec.	Fx .87	Measured Temperature °F.	Calculated Temperature °F.	Fx .87	Measured Temperature °F.	Calculated Temperature °F.
0	0	414	400	0	414	400
2	0.174	414	407	0	415	400
5	1.00	417	438	0.10	423	404
7.5	2.04	435	477	0.67	435	433
10	2.96	478	512	1.47	460	466
15	4.65	547	576	3.22	509	522
20	5.67	599	614	4.35	552	564
30	6.75	660	655			
40	7.15	682	670			
50	7.15	682	670			
60	6.90	661	650			
100	6.15	639	632			
120	5.75	604	617			
150	5.40	583	604			
180	5.17	552	595			

tances from 0.25 to 0.70 in. from the weld center line, Figs. 8 and 9 give values from 0.60 to 1.7 in. Figures 10, 11 and 12 show the same values of $F(s, d)$ plotted as a function of time for various distances in the range from 0.25 to 0.70 in.

Values of F_d, obtained as explained above, required in Equation 8 to give values of space temperature gradient in degrees Fahrenheit per inch are shown in Table 3. Typical curves of F_d vs. distance in inches are shown in Fig. 13.

Values of F_s, obtained as explained above and giving values of cooling rate, or in some cases heating rate, in degrees Fahrenheit per second are shown in Table 4. As it was not possible to determine slope accurately for small values of time, values of F_s are not given for values of time less than 4 sec.

Equation 1 shows that $(T-T_0)$ and consequently F, F_d and F_s are directly proportional to the input factor ($I.\ F.$). This makes it possible to determine values of the coefficients, F, F_d and F_s for preheat temperatures directly from these coefficients at room temperature since input factors for several such temperatures were obtained in a previous investigation.* To obtain values of F, F_d or F_s for a weld made with a $^3/_{16}$-in. electrode on a $^1/_2$-in. plate at an initial plate temperature of 400° F., multiply the corresponding tabular value by the ratio of the input factor at 400° F. to the input factor of room temperature, namely 0.87. The multipliers for plate temperatures of 32 and 210° F. are 1.02 and 0.95, respectively. These multipliers are given in Table 5.

As a check of the validity of the extension to preheat temperatures two temperature-time curves were re-recorded with the initial plate temperatue at 400° F. For comparison, the calculated and measured values of temperature are shown in Table 6. Considering the difficulties involved in obtaining a uniform preheat temperature, the table shows a sufficiently close check to corroborate the theory.

ACKNOWLEDGMENT

The original experimental work and part of the mathematical development was done at Rensselaer Polytechnic Institute under a contract with the Office of Scientific Research and Development; Contract OEMSR-1030; and was included in a report entitled "Evaluation of Factors Affecting Crack Sensitivity of Welded Joints, Part I." Subsequent refinements in the mathematical treatise were performed at Rensselaer Polytechnic Institute under the sponsorship of the Weldability Committee of the Welding Research Council of the Engineering Foundation.

Review of Current College Research

OVER 4000 current college and university research projects in engineering subjects, representing expenditures of over $35,000,000, are listed by title in the 1949 *Review of Current Research*, published this week by the Engineering College Research Council of the American Society for Engineering Education.

Entries in the book from 82 educational institutions which hold membership in the Research Council describe the administrative policies for conducting engineering research and list the responsible personnel, research expenditures, short courses and conferences of special interest and the titles of all engineering research studies currently active at each institution.

Use of the volume is facilitated by a breakdown of research projects according to the engineering departments involved, and by a complete index to research project subjects.

Copies of the book, paper bound and including more than 180 pages, are available ($1.75 postpaid) from the Engineering College Research Council. Address orders to F. M. Dawson, Chairman, in care of the College of Engineering, State University of Iowa, Iowa City.

Relief of Residual Stress by a Single Fatigue Cycle

by W. P. Wallace and J. P. Frankel

THERE appears to be increasing interest in the effect of the residual stress on the fatigue properties of aircraft members. In view of this fact, the effect of the external load on the magnitude of this stress must be accurately known.

In their investigations on notched mild steel plate, Norton, Rosenthal and Maloof[3] stated that "If residual tension were induced at the bottom of the notch by some previous treatment, a gradual removal of the residual tension may be anticipated as a result of overstressing." Also, they showed that the stress gradient at the notch resulting from bending had no effect on plastic flow in the immediate vicinity of the notch.

Rosenthal, Sines and Zizicas[2] induced residual compressive stresses in notched 61S aluminum specimens and subjected them to reversed bending stresses; they found a redistribution of residual stress when the specimens were cycled. In fact, the stress at the notch, after such tests, was found to be zero.

On the other hand, Hall and Parker's[1] results indicate that the nominal fatigue limit for mild steel is reduced approximately 50% by induced residual tensile stresses in notched specimens. To check further the behavior of induced residual tensile stresses after cyclic loading, the following investigation was made.

An aluminum alloy 61S specimen, 0.353 x 3 x 18 in., was prepared with a notch on one edge in the middle of specimen length. This alloy was chosen because of its small crystallite size, allowing easier X-ray stress measurement. The notch was 0.20 in. wide by 0.72 in. deep with 0.100 in. radius; the bottom of the notch was polished with 4/0 emery paper.

Residual tensile stresses at the bottom of the notch were induced by heating the edge of the specimen away from the notch while the opposite edge containing the notch was immersed in a tank of water to a depth halfway between the base of the notch and the heated edge. The magnitudes of these residual stresses were determined by X-ray techniques described by Rosenthal, Sines and Zizicas,[2] and are plotted as circles in the accompanying figure.

The specimen was then subjected to one complete cycle of stress, of nominal value 6000 psi. across the notch section, or approximately 15,000 psi. at the notch (assuming elastic distribution of the stresses). Yield strength for this alloy was 16,300 psi. The magnitudes of the stresses after this treatment were determined in the same manner as above, and are plotted as triangles in the accompanying figure.

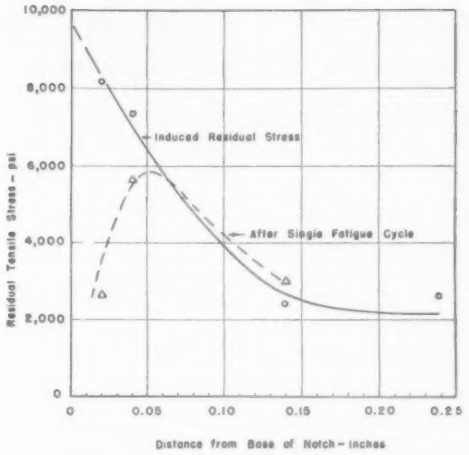


Fig. 1 Relief of residual stress by a single fatigue cycle

Results are summarized as follows:

Distance from notch, in.	0.02	0.04	0.14
Induced residual stress, psi.	8100	7300	2360
After one cyclic load, psi.	2600	5580	2970

From the above results, it may be concluded that the residual stresses at the base of the notch are relieved during the first cycle of a fatigue limit test. This is to be expected when, as a first approximation, the magnitude of the applied cyclic stress causes the sum of itself and the residual stress to exceed the yield point; e.g., if the yield point were 16,000 psi. and the residual stress 10,000 psi., then an applied load inducing a stress of 15,000 psi. would, after a complete cycle, remove (10,000 + 15,000) − 16,000 or 9000 psi., leaving a residual stress of 1000 psi. These results confirm the findings of the investigators cited in the first two paragraphs. Therefore, it is difficult to reconcile Hall and Parker's results with the authors' findings.

ACKNOWLEDGMENTS

The authors are indebted to Prof. D. Rosenthal for his kind criticism of this paper, and to Mr. George Sines for the preparation of the specimen.

Bibliography

1. Hall, L. D., and Parker, Earl R., "Effect of Residual Tension Stress on the Fatigue Strength of Mild Steel," THE WELDING JOURNAL, **27** (8), Research Suppl., 421-s to 425-s (1948).
2. Rosenthal, D., Sines, G., and Zizicas, G., "Effect of Residual Compression on Fatigue," *Ibid.*, **28** (3), Research Suppl., 99-s to 103-s (1949).
3. Norton, J. T., Rosenthal, D., and Maloof, S. B., "X-Ray Diffraction Study of Notch-Bend Test," *Ibid.*, **25** (5), Research Suppl., 269-s to 276-s (1946).

W. P. Wallace and **J. P. Frankel** are associated with the Dept. of Engineering, University of California, Los Angeles, Calif.

Comparison of Radiation from Argon-Arc Welding with that of Metallic-Arc Welding

by E. van Someren and E. C. Rollason

ARISING out of the work published in THE WELDING JOURNAL, September 1948, we were asked to make a comparison of the radiation from argon-arc welding with that of ordinary welding. The argon-arc equipment available was of an early type and was not capable of maintaining an arc at 280 amp. as used for the previous measurements. The electrode holder contained a $^3/_{16}$ in. diameter tungsten electrode surrounded during welding by a stream of argon at 5 to 7 cu. ft. per minute. The a.-c. arc was maintained by a high-frequency discharge throughout the welding period.

The previous tests were made on mild steel and as argon-arc welding is not usually used on mild steel, stainless steel was selected as the material for comparative tests.

EQUIPMENT USED

For visible radiation, comparative tests on the brightness of the arc were made with a photoelectric cell of the selenium type incorporating a pale green filter so as to give an approximate match to the color sensitivity of the eye. Neutral filters of blackened wire gauze were used to bring the brightness down to the intensity level at which the photocell is normally used.

Measurements of total heat radiated were made with a vacuum thermopile fitted with a quartz window 1.8 mm. thick. In both series of measurements the viewing instrument was 141 cm. from the arc and the results were calculated to radiation at 31.6 cm. from the arc (by multiplication by 20).

OBSERVATIONS OF THE ARC

Measurements of the brightness were made viewing the arc horizontally so that radiation reflected from the molten pool did not contribute to the measurements. The current of 130/140 amp. was made equal for the argon-arc weld and for the a.-c. weld with an 8-gage Nicrex MC electrode; in both cases the plate was stainless steel $^3/_{16}$ in. thick. The arc length was not the same for the two processes, but was held at its normal value for the current used. The measurements showed that the ordinary a.-c. arc is about six times as bright as the argon arc; the lack of steadiness on both sets of observations indicates that the ratio of brightnesses varied from 4 to 8. The tolerance of the eye is such that this could be compensated for by using a welding glass one shade number lighter for the argon arc than for ordinary a.-c. welding with the same current. For the arc used, a shade 9 filter would be appropriate instead of the usual shade 10.

The measurements of total heat radiated were made from the same position as the above tests, i.e., with almost horizontal viewing; and also looking down at the arc at an angle of 45° in a plane at right angles to the direction of welding. The results were converted to milliwatts per square centimeter from the calibration factor of the thermopile and galvanometer used and were corrected for distance so as to be comparable with the measurements quoted in the previous report. The figures are given in the following table:

Viewing	Argon-arc, milliwatts/cm.^{2}	A.C. in air, milliwatts/cm.^{2}
Horizontal	19	21
At 45°	25	42
Previous test, mild steel, 280-amp. arc at 45°	...	135

CONCLUSIONS

The similarity of the horizontal total radiation from the two arcs combined with the difference in the horizontal luminous radiation indicates that the temperature of the arc column is lower in the argon arc than for the a.-c. arc in air. This would account for the fact that the two arcs with approximately the same energy input (as measured by current) give equal intensities of total radiation but a different distribution: The argon arc being poorer in ultraviolet and visible light is therefore relatively richer in infrared radiation. The difference may be due to the higher heat conductivity of argon compared with air.

The comparison of total radiation at an angle of 45° shows a considerably higher energy output from the a.-c. arc in air. This difference indicates that the pool of molten metal is larger for the a.-c. arc than for the argon arc at the same current; a fact which is obvious from inspection of the welds produced.

It is therefore recommended that for argon-arc welding, a welder should select welding glasses one shade lighter than for a.-c. arc welding with the same current value. Where only glasses with even-numbered shades are available, the same glass should be used for argon-arc welding as for metallic-arc welding at the same current value.

Acknowledgments are made to the Directors of Murex Welding Processes Ltd. for permission to publish this note.

E. van Someren and **E. C. Rollason** are with Murex Welding Processes Ltd., Waltham Cross, Herts, England.

This article reprinted from the June 1949 issue, *Trans. Inst. Welding (London)*.

The Statistical Part in Welding Investigations

Discussion by J. Manuele and Roscoe C. Byers

Miss Day has prepared an excellent paper and there is no doubt that a considerable amount of research went into its preparation. The bibliography alone would justify publication of the paper, because of its completness. The list of references can be of tremendous value to researchers in the field of statistical applications to industrial and research problems.

Unfortunately the author has chosen to discuss a hypothetical problem. With so many practical problems literally shouting to be resolved, and with so many production situations in need of being straightened out, it is a mystery to us why she did not take an actual shop situation for discussion. It would certainly have been of much more interest and of greater value to practical welders and other workers in this field.

The paper is aimed at experimenters and researchers. In the words of the author, the first part of the paper deals "with the structure of the experiment," and the second part of the paper deals "with the evaluation and interpretation of the experimental data." In our humble opinion, the author has very ably achieved both these aims. She has explained very admirably, and very lucidly, the design of an experiment for studying the problem of electric arc welding. She has also shown very clearly the method of making the necessary calculations and how to draw correct inferences from them.

Therefore, any criticism of the paper resolves itself in a criticism of the mathematical tools used, and there is no room for criticism in this respect. Perhaps the paper is somewhat long. However, this can be excused in the interest of lucidness, since this subject can be very obscure if not properly handled. The author takes a long time to get started, and the lengthy discussion of the early part of the paper may cause some readers to lose interest before they have an opportunity to appreciate the very excellent manner in which the "Statistical Analysis of the Planned Experiment" is treated.

Without any doubt, the analysis of variance is the most practical technique for studying interaction effect, and the author has done well to spend so much time in an explanation of this method. Incidently, she has done this admirably well.

In our own experience, we have found that the analysis of the variance method of investigating shop production problems is always productive of results. We like this method of investigation because we can take data from actual shop operations without the need of resorting to the rule-of-thumb, and somewhat antiquated, method of "vary one variable, and hold the others constant." Since the author has very ably discussed this phase of the problem it would be superfluous for us to try to explain it again.

There is no question but what Miller has done an excellent job of relieving some of the heavier portions of the paper by means of his illustrations, and they do help to explain the text very admirably.

In the Appendix, the author discussed the "Estimate of True Variance" and the computation of individual variance. It appears that the "Estimate of True Variance" for chromium, as well as the total variance may be too high. Probably, the author can explain this satisfactorily.

In preparing, or even in reviewing, a paper of this kind, one is faced with the question "What is the practical application of the material discussed; where can these principles be used; will they actually help in getting out production, and in lowering costs, or are they just window trimming?" Speaking from experience, the tools presented by the author belong in the statistical toolbox of every quality control engineer who calls himself such. These methods will point up assignable causes, the correction of which may increase production fantastically, and cut manufacturing costs to the bone.

Frequently, when production bottlenecks occur, it is customary to adopt all corrective measures than can be thought up by all the people who come in close proximity to the problem. Sooner or later, the bottleneck is broken, but we do not know what caused it, and we do not know definitely what broke it. In this paper, we have a tool which will tell us whether a bottleneck exists, and what might be the most likely cause of it. Instead of stumbling around in the dark, we are offered a light so we can find our way around.

Discussion by Wade R. Weaver

First of all I should like to compliment the authoress of this paper on her carefully thought out, concise, relatively simple explanation, in language at least comparatively free from confusing terms, of a most complicated situation. The statement of the problem involved and the method of attack should be readily understood by anyone familiar with research and experimentation.

The salient points of the lesson the reader should have learned are about as follows: First, that a properly designed plan of experiment should make it possible, after suitable treatment by certain statistical procedures, to obtain the desired answer much sooner, cheaper and to greater limits of accuracy and assurance than would be

J. Manuele is Director and **Roscoe C. Byers** is Staff Assistant, Headquarters Quality Control, Westinghouse Electric Corp., East Pittsburgh, Pa.

Paper by B. B. Day published in Research Supplement, October 1949 issue of THE WELDING JOURNAL.

Wade R. Weaver is Director of Quality Control, Republic Steel Corp., Cleveland 1, Ohio.

possible by conventional methods. Second, that in addition these techniques make possible the inclusion of facts in the decision which would otherwise be virtually impossible to evaluate. Third, the very valuable information that it is no longer essential to confine experimental work to the pilot plant, the laboratory or the test tube; it can now be done on a production scale with production material, conditions and methods.

All of these remarks apply up to about page "Analysis of a Statistically Planned Experiment". From here on a high percentage of the readers probably became somewhat exhausted, for the rigors of trying to understand and follow the mathematics of the development of even one of the simpler phases of this complicated technique are too great for most of us to cope with. It would seem to me that if authors of treatises such as this could find some way to merely tell the reader that there were available for use techniques to do thus and so, familiar to competently trained individuals, without trying to show him how they work, more extensive and beneficial results might accrue. This leads us to a fourth important conclusion to be gleaned from this paper; there is almost mandatory need for experimental work to be carried on by a setup which includes thoroughly grounded statistical assistance. Much as we may dislike to include an abstract science like mathematics in the study of a science like welding, recent events have proved we shall be well advised to do so. These time-saving, fact-finding, opinion-eliminating techniques are available to us; it is up to us to use them.

Notch Sensitivity of Mild Steel Plates

Discussion by Perry R. Cassidy

The author has tested nine steels in a range of thickness, with variable deoxidation practice from rimmed to killed. Aside from silicon, the steels are very uniform in chemistry and tensility.

The paper indicates close agreement in transition temperature obtained by tear, notched-tensile and notched-bend tests with those from Charpy inpact tests using the Izod notch of standard depth or of the same depth as the standard keyhole Charpy notch. The transition temperatures obtained by the keyhole Charpy notch are about 100 F. lower than for the Izod notch.

The Unfired Pressure Vessel Code of the A.S.M.E., 1949 edition as well as A.S.T.M. Specification A300–47T, covering steel plate for pressure vessels at low temperature, have similar requirements for impact testing steels for service below −20 F. They permit the use of the keyhole or Izod notch. The 1950 edition of the Unfired Pressure Vessel Code permits only the keyhole notch.

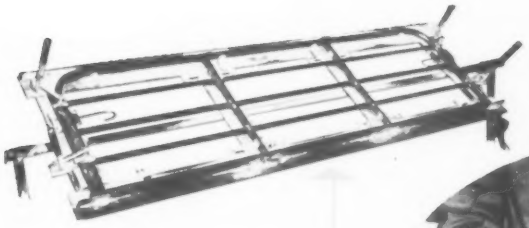
Perry R. Cassidy is Executive Asst., The Babcock & Wilcox Co., Boston 10, Mass.

Paper by A. B. Bagnar was published in the Research Supplement to the October, 1949 issue of The Welding Journal.

The minimum requirements for both Codes are an average for three specimens of not less than 15 ft.-lb. at the operating temperature, with one specimen permitted to have a minimum impact strength of 10 ft.-lb.

The paper consistently indicates that only the Izod notch correlates with the tear, tensile and bend tests.

It is a well-known fact that subsize impact test specimens, particularly of the keyhole type, give lower transition temperatures than full width specimens. I do not imply that the Unfired Pressure Vessel Code is unsafe in permitting proof of the safety of low-temperature vessels to be established by the Charpy keyhole notch. We are, however, in great need of a logical criterion for safety of a pressure vessel for service at lower than −20 F. The results reported in this paper seem to point to the use of a modified Izod notch Charpy specimen with the same depth of notch as the Charpy keyhole. With such specimen (V5) most of the transition temperatures were at 15 ft.-lb. impact strength. Any pressure vessel which contains a crack in the shell is notched sharply more in the order of the Izod than the Charpy notch. If such vessel is operated at temperatures below 100 F. instead of −20 F. and constructed of steels such as described in the paper, the presence of a crack at a zone of high stress requires only the application of a shock of sufficient severity to result in brittle failure of the vessel. The possibility of the occurence of such shock in service at low temperature should be a guide to the design engineer as to the criterion he will use in determining the suitability of the material selected.



Safety slide for hospital bed. 42 half-inch long tack welds plus 6 continuous welds are made on .042" cold rolled steel in 23 minutes, including assembly time.

SIMMONS STEEL FURNITURE *is Bronze Welded*

Bedside cabinet. 2 reinforcing welds, 2 inches long, are made on 20-gage cold rolled steel in 54 seconds.

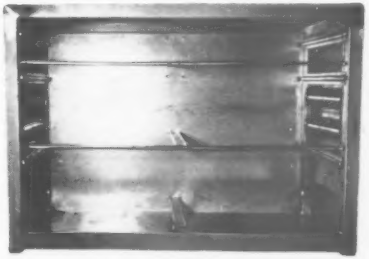
PRODUCT IS STRONGER

ASSEMBLY IS FASTER

COSTS ARE LOWER

COMPARATIVE SAVINGS:
Using ANACONDA 997 (Low Fuming) Bronze versus steel welding rod on same operations

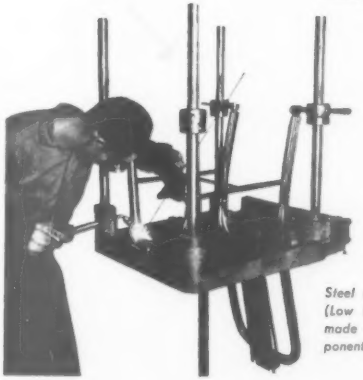
40 to 60%



Steel dresser. 36 welds are made on 20- and 22-gage cold rolled steel. Total time, including assembly, is less than 6 minutes.

The Simmons Company adds: "Under actual testing, we have a much stronger unit today than if we were using steel welding, due to the fact that the lower bronze-welding temperatures do not weaken the joint areas."

If you do either production or repair welding, write for Publication B-13. It covers *all* ANACONDA Welding Rods, their applications and procedures for their use. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 49157



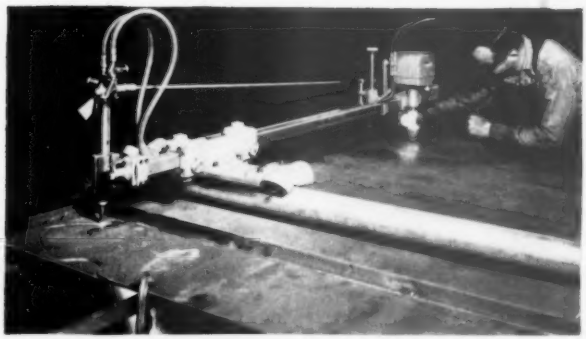
Steel chair. 56 ANACONDA 997 (Low Fuming) Bronze welds are made on each chair, with components aligned in welding fixture.

You can depend on

ANACONDA

"We can't say enough about Airco's NEW No. 3 Monograph . . . its portability, accuracy and shape cutting versatility make it a MUST for every metal working shop..."

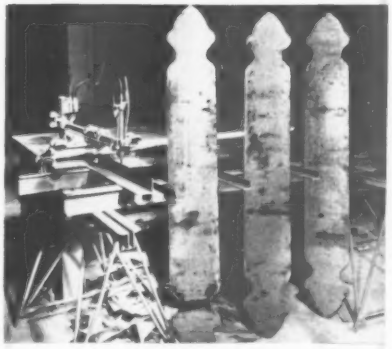
Says Mr. J. C. Hustad, President
Hustad Company, Minneapolis, Minn.



Used for machine gas cutting of special structural shapes at Hustad, the Airco No. 3 Monograph has more than proved its ability to meet the demand for straight line, circle and bevel cutting, with an extremely high degree of accuracy.

Further, with a cutting area of 32 inches by 56 inches, it gives excellent results in cutting most any steel shape up to 8 inches thick . . . and a 6-foot 8-inch rail can be added, extending the cutting area indefinitely.

This NEW machine is the lowest priced machine of its type in the field (only $695, including a manual tracing device, torch, tip, tubular rail, hose and carrying case). Also, it is portable—the machine itself weighs but 110 lbs. and the tubular rail 35 lbs. The entire unit is packed in a carrying case which can be conveniently handled by two men.



SPECIAL TRIAL OFFER
(Good in Continental U.S.A. Only)

If you would like to try this machine for two weeks *in your own shop on your own work*, just drop a letter to your nearest Airco office or authorized Airco dealer and they will advise you how a shop-trial can be arranged . . . or, if you would like a descriptive folder (ADC-660) they will be glad to send you a copy.

This shows a clevis for a steel mill guide cut from 6" plate—note the smoothness of the cut, reducing considerably machining cost and time.

AIRCO **AIR REDUCTION**
Offices in Principal Cities

Headquarters for Oxygen, Acetylene and Other Gases . . . Calcium Carbide Gas Cutting Machines . . . Gas Welding and Cutting Apparatus and Supplies . . . Arc Welders, Electrodes and Accessories.